THE REINFORCING EFFECTS OF GENERAL ILLUMINATION DURING CHAINED SCHEDULES OF FOOD PRESENTATION

By

RONALD F. ALLEN

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1990

ACKNOWLEDGEMENTS

Although there are a myriad of individuals who have contributed to my being at this moment and position in my life, I have only the space to acknowledge the most prominent.

My parents, Henry and Celia Allen, have never wavered in their support or love. My achievements are theirs as well. I can only hope that they realize my eternal love and gratitude, and share in my satisfaction.

Much of my education has come informally from what might be called my "intellectual community." A partial list of the residents of my community would include William Walker, Frank Webbe, Michael Gardner, Gregory Galbicka, Michael Stoutimore, Jeff Kupfer, Anne Kupfer, and my wife Julia Allen.

The main focus of my formal education has been the result of my graduate committee: Marc Branch, Don Dewsbury, Henry Pennypacker, and William Wolking. Each is a scientist and I am more so for having known them.

Special mention must be made of E.F. Malagodi. He has been my mentor and friend. Because of him I am not only a better scientist, but a truly radical, Radical Behaviorist. How do you thank someone for shaping your "world view?"

Also, without pretense, I would like to thank B.F. Skinner.

Finally, how do I thank my wife Julia, who has patiently paid as many dues for my education as I have? Her love is the meaning for this and all achievements, including Eric Michael Allen, my son and second wind in life. To my wife and my son I dedicate my second wind, for what it's worth.

TABLE OF CONTENTS

		Page
ACKNOWLEDGEMENTS		ii
LIST OF TABLES		vi
LIST OF FIGURES		vii
ABSTRACT		ix
CHAPTERS		
ONE	GENERAL INTRODUCTION	1
TWO	EXPERIMENT ONE	5
	Method	6
	Subjects	6
	Apparatus	6
	Procedure	7
	Results	10
	Discussion	22
THREE	EXPERIMENT TWO	30
	Method	33
	Subjects	33
	Apparatus	33
	Procedure	33
	Results	35
	Discussion	40
FOUR	EXPERIMENT THREE	47
	Method	49
	Subjects	49
	Apparatus	49
	Procedure	49
	Results	50
	Discussion	59

FIVE EXPERIMENT FOUR 68

Method 69
Subjects 69
Apparatus 69
Procedure 70
Results 70
Discussion 78

SIX GENERAL DISCUSSION 87

REFERENCES 96

BIOGRAPHICAL SKETCH 105

LIST OF TABLES

Table		Page
1	Sequence of conditions during Experiment One and the number of sessions under each for Pigeons 1150, 4214, and 3519	9
2	Sequence of conditions during Experiment Two and the number of sessions under each for Pigeons 1150 and 4214	34
3	Sequence of conditions during Experiment Three and the number of sessions under each for Pigeons 1150, 2225, and 3775 . . .	51
4	Sequence of conditions during Experiment Four and the number of sessions under each for Pigeons 1150, 2225, and 3775 . . .	71

LIST OF FIGURES

Figure		Page
1	Representative cumulative records for each condition of Experiment One for P-1150 . . .	12
2	Quantitative summaries of keypeck rate and component quarter-life for each condition of Experiment One for P-1150	15
3	Representative cumulative records for each condition of Experiment One for P-4214 . . .	17
4	Representative cumulative records for each condition of Experiment One for P-3519 . . .	19
5	Quantitative summaries of keypeck rate and component quarter-life for each condition of Experiment One for P-4214	24
6	Quantitative summaries of keypeck rate and component quarter-life for each condition of Experiment One for P-3519	26
7	Representative cumulative records for each condition of Experiment Two for P-1150 . . .	37
8	Representative cumulative records for each condition of Experiment Two for P-4214 . . .	39
9	Quantitative summaries of keypeck rate and component quarter-life for each condition of Experiment Two for P-1150	42
10	Quantitative summaries of keypeck rate and component quarter-life for each condition of Experiment Two for P-4214	44
11	Representative cumulative records for each condition of Experiment Three for P-1150 . .	53
12	Representative cumulative records for each condition of Experiment Three for P-2225 . .	55
13	Representative cumulative records for each condition of Experiment Three for P-3775 . .	57

14 Quantitative summaries of keypeck rate and component quarter-life for each condition of Experiment Three for P-1150 61

15 Quantitative summaries of keypeck rate and component quarter-life for each condition of Experiment Three for P-2225 63

16 Quantitative summaries of keypeck rate and component quarter-life for each condition of Experiment Three for P-3775 65

17 Representative cumulative records for each condition of Experiment Four for P-1150 . . 73

18 Representative cumulative records for each condition of Experiment Four for P-2225 . . 75

19 Representative cumulative records for each condition of Experiment Four for P-3775 . . 77

20 Quantitative summaries of keypeck rate and component quarter-life for each condition of Experiment Four for P-1150 80

21 Quantitative summaries of keypeck rate and component quarter-life for each condition of Experiment Four for P-2225 82

22 Quantitative summaries of keypeck rate and component quarter-life for each condition of Experiment Four for P-3775 84

Abstract of Dissertation Presented to the Graduate School of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

THE REINFORCING EFFECTS OF GENERAL ILLUMINATION DURING CHAINED SCHEDULES OF FOOD PRESENTATION

By

RONALD F. ALLEN

May 1990

Chairperson: E.F. Malagodi
Major Department: Psychology

Keypecking for five pigeons was maintained under either two- or three-component chained schedules of food presentation. The component schedule in each of the chained schedules was a fixed-interval (FI) of one or two minutes duration. Across experimental conditions, the presence of ambient illumination provided by the experimental chamber houselight was manipulated. For each bird, first-component response rates were enhanced considerably when the houselight was extinguished during the first component and illuminated during the second component. Several experiments were performed attempting to isolate the source of the rate-enhancing properties of this houselight illumination arrangement. The results of these experiments suggest that the increase in first-component response rates was not simply the result of the disinhibition of responding by the removal of ambient illumination, but appeared to be the

result of the reinforcement of responding by the onset of houselight illumination with the second component. Additionally, the apparent reinforcing properties of houselight illumination resulted neither from the chronic association of the illuminated houselight with the terminal component of the chained schedule, nor from generalization from the illumination of the food hopper mechanism. The results of the present series of experiments relate to previous demonstrations of illumination-reinforced responding and to experiments employing changes in illumination as arbitrary or neutral experimental stimuli. Two conclusions based on the present results are (1) houselight illumination can function as a reinforcer under a variety of experimental arrangements, and (2) interpretations of data from experiments in which illumination of the houselight has served as a discriminative stimulus must be re-examined with respect to possible reinforcing characteristics of illumination.

CHAPTER ONE

GENERAL INTRODUCTION

Three forms of second-order schedules have been studied extensively: chained schedules comprised of fixed sequences of component schedules of discriminative-stimulus changes (e.g., Gollub, 1958; Kelleher & Gollub, 1962); brief-stimulus schedules with component schedules of briefly presented stimuli (e.g., Kelleher, 1966b); and token reinforcement schedules with component schedules of token presentations which may be exchanged occasionally for unconditioned reinforcement (e.g., Kelleher, 1958; Malagodi, 1967a,b,c). These studies generally have followed the strategy outlined by Kelleher (1966a) of treating within-component rates and patterns of responding as unitary responses that are directly maintained by presentation of component stimuli and ultimately maintained by the intermittent association of component completion with primary reinforcement.

This strategy of viewing second-order schedules as "schedules of schedules" and the capacity for second-order schedules to maintain long, orderly sequences of responding in the absence of frequent primary reinforcement has led to the analysis of a wide range of questions pertaining to

(1) the formation and maintenance of functional units of behavior (Marr, 1979), (2) interactions between form and parameter value of component schedule with form and parameter value of primary reinforcement schedule (e.g., Lee & Gollub, 1971; Malagodi, Webbe, & Waddell, 1975; Waddell, Leander, Webbe, & Malagodi, 1972; Webbe & Malagodi, 1978), (3) the effect of direct association of component schedule stimuli and primary reinforcement (e.g., Byrd, 1971; Kelleher & Fry, 1962), (4) putative conditioned reinforcing and discriminative functions of component schedule stimuli (e.g., Byrd & Marr, 1969; de Lorge, 1967, 1969, 1971; Malagodi, DeWeese, & Johnston, 1973; Stubbs, 1971), and (5) the chronic maintenance of responding through response-contingent presentation of electric shock (e.g., Byrd, 1972; Gardner & Malagodi, 1981), electrical stimulation of the brain (e.g., Beninger & Milner, 1977), and psychoactive agents (e.g., Goldberg, Kelleher, & Morse, 1975).

Although the results of many of these experiments have revealed marked similarities among the overall patterns of responding maintained under comparable second-order chained, brief-stimulus, and token reinforcement schedules (Gollub, 1977; Kelleher, 1966a; Marr, 1969, 1979), significant differences are evident as well. The overall rates of responding and the overall length of the sequences of responding maintained under brief-stimulus and token reinforcement arrangements are considerably greater than those

maintained under comparable chained schedules (e.g., Findley, 1962; Findley & Brady, 1965; Gollub, 1958; Kelleher, 1966a; Malagodi et al., 1973). These differences correspond to the low rates of responding and prolonged pauses that characterize the early portions of multi-component or extended chained schedules (Kelleher & Gollub, 1962). Suggested accounts for these performances have emphasized the organization and function of component stimuli within the chained schedule arrangement. Because the stimuli correlated with early components of the chained schedule are never associated with the presentation of primary reinforcement, they may generate or occasion low rates of responding and extended pausing (Byrd, 1971; Gollub, 1977; Kelleher & Fry, 1962; Kelleher & Gollub, 1962). Alternatively, because the stimuli correlated with the intermediate components of an extended chained schedule are temporally removed from the presentation of primary reinforcement, their onset provides only weak reinforcement for responding in earlier components of the chained schedule (Gollub, 1977; Kelleher & Gollub, 1962).

In addition to the organization and function of component stimuli, the physical composition of the stimulus presentation is an important determinant of responding under second-order schedules. Stubbs (1971) reported greater within-component response patterning under a brief-stimulus schedule when keylight or houselight illumination (either separately or in combination) was employed as the brief

stimulus, than when brief removal of houselight illumination accompanied component completion. Staddon (1972) and Zeiler (1972) similarly found the removal of houselight illumination to exert little discriminative control over responding under a reinforcement omission or percentage reinforcement procedure (Ferster & Skinner, 1957). In a recent experiment from this labor-atory, Kupfer and Malagodi (in preparation) found enhanced within-component response patterning and greater local rates of responding under a brief-stimulus schedule when houselight illumination, rather than paired or nonpaired keylight illumination, functioned as the brief stimulus.

These and similar results (Kish, 1966) suggest that a great variety of stimuli function as unconditioned or pre-experimentally established reinforcers. Such results are particularly important with respect to houselight illumination. The chamber houselight is common to most operant experimental arrangements and has been employed frequently in a discriminative function. However, little discussion of the existence of any potentially reinforcing properties of such illumination has occurred. The demonstration of such extra-experimental properties associated with houselight illumination would serve to compromise the interpretation of any data employing it as an experimental stimulus. The present series of experiments examined the effects of the presence of houselight illumination during schedules of food delivery and attempted to isolate the source of the reinforcing properties of illumination onset.

CHAPTER TWO

EXPERIMENT ONE

Illumination from the chamber houselight has served two identified functions in previous experiments—to provide ambient illumination and as an arbitrary (i.e., neutral) discriminative stimulus associated with some conditional aspect of reinforcement presentation. Examples of the latter include use of changes in houselight illumination to accompany self-imposed time-out periods during schedules of food presentation (e.g., Azrin, 1961; Dardano, 1973), correlated with periods of extinction interpolated within fixed-interval (FI) schedules of food presentation (e.g., Dews, 1962), and as part of a brief-stimulus complex during second-order schedules of food presentation (e.g., Stubbs, 1971).

In the present experiment, the presence of houselight illumination was manipulated during the component schedules of a chained schedule of food presentation. A chained schedule was employed to isolate any reinforcing and discriminative properties of illumination by examining responding during the component schedule preceding illumination onset and in the presence of illumination, respectively.

Method

Subjects

Three adult male White Carneaux pigeons (P-1150, P-4214, and P-3519) were maintained at 80% of their free-feeding body weights. Each bird had previous exposure to simple schedules of food presentation prior to the present experiment and each was individually housed with water and health grit continuously available. General illumination was provided in the housing facility on a regular 14-h On, 10-h Off cycle. Sessions were conducted only during the 14-h On cycle.

Apparatus

A commercially available Lehigh Valley Pigeon Test Chamber (model 1519) equipped with a standard three-key stimulus panel was used. Only the right key was operative and could be transilluminated with different colored lights. The other keys were covered with metal plates. A minimum force of 25g (0.25N) was required to operate the circuitry. The chamber could be illuminated by a 1.4W clear houselight bulb which was shielded from beneath with a metal cover and located 4.5cm above the center key. A food hopper containing mixed grain could be made available through a square (5.7cm x 5.7cm) aperture in the stimulus panel located 9cm below the center key. Illumination of the raised food

hopper was provided by a 1.4W clear bulb mounted above the feeder mechanism.

Standard electromechanical scheduling and recording equipment was located in an adjacent room. Ventilation was provided by an exhaust fan mounted to the chamber. White noise was present at all times.

Procedure

Each pigeon was exposed initially to a fixed-interval 2-min (FI 2-min) schedule of food presentation. Under these conditions the key was transilluminated red and the first response after two minutes produced 4-s access to mixed grain. During grain presentation both the keylight and the houselight were turned off and the raised food hopper was illuminated with white light.

Following several sessions under these conditions, a chained FI 2-min FI 2-min schedule of grain presentation was introduced. Under this schedule, the response key was transilluminated yellow during the initial FI 2-min schedule (the first component) and the first response after two minutes changed the key illumination from yellow to red and initiated a second FI 2-min schedule (the second component). The first response after two minutes in the second component produced grain delivery. After grain delivery, the first component was again in effect. Birds P-4214 and P-3519 were exposed to both chained FI 2-min FI 2-min and chained

FI 1-min FI 1-min schedules, while the chained FI 2-min FI 2-min schedule was always in effect for P-1150.

The experimental conditions of Experiment One consisted of manipulations of the presence of houselight illumination during the two components. These manipulations included (1) houselight on throughout both components (ON/ON), (2) houselight on during only the first component (ON/OFF), (3) houselight on during only the second component (OFF/ON), and (4) houselight always off (OFF/OFF). The sequence of experimental conditions and the number of sessions under each are summarized in Table 1. The number of responses and duration of time spent within each component were recorded during each experimental session. Additionally, each component period was divided into ten equal segments, or bins, and the total number of responses occurring within each bin was recorded for each session. From these absolute measures two derived measures were obtained: average component keypeck rate and average component quarter-life. Quarter-life is an index of the distribution of responding within a time period and represents the proportion of the time period having elapsed prior to the occurrence of one fourth of the total responses recorded during that interval (Gollub, 1964; Herrnstein & Morse, 1957). Each experimental condition was in effect for at least twenty sessions and until no systematic changes were evident in the daily session measures for twenty sessions. Typically, sessions were run six days per week and were terminated following fifteen grain

Table 1

Summary of the experimental conditions (in order) for Pigeons 1150, 4214, and 3519 with the number of sessions under each condition.

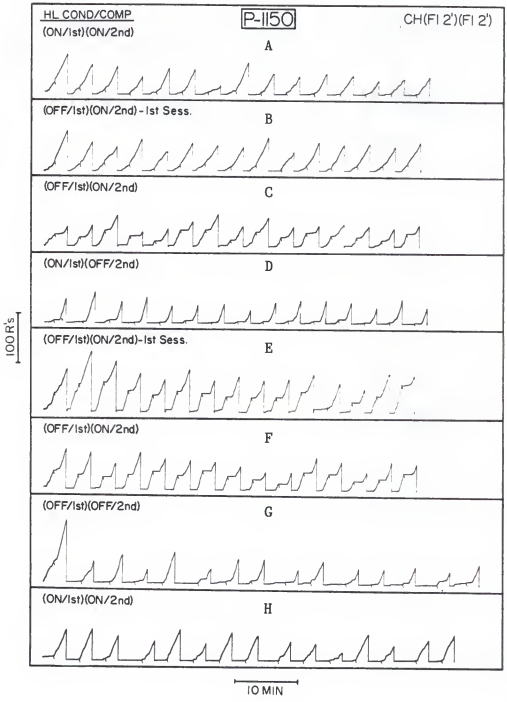
Subject	Schedule	Houselight Condition	Number of Sessions
P-1150	CH (FI 2-m)(FI 2-m)	ON / ON	38
	CH (FI 2-m)(FI 2-m)	OFF / ON	30
	CH (FI 2-m)(FI 2-m)	ON / OFF	48
	CH (FI 2-m)(FI 2-m)	OFF / ON	46
	CH (FI 2-m)(FI 2-m)	OFF / OFF	96
	CH (FI 2-m)(FI 2-m)	ON / ON	55
P-4214	CH (FI 2-m)(FI 2-m)	ON / ON	50
	CH (FI 2-m)(FI 2-m)	OFF / ON	158
	CH (FI 1-m)(FI 1-m)	OFF / ON	63
	CH (FI 1-m)(FI 1-m)	ON / ON	81
	CH (FI 1-m)(FI 1-m)	OFF / ON	50
	CH (FI 1-m)(FI 1-m)	ON / OFF	117
	CH (FI 1-m)(FI 1-m)	OFF / OFF	55
	CH (FI 1-m)(FI 1-m)	ON / ON	32
P-3519	CH (FI 2-m)(FI 2-m)	ON / ON	42
	CH (FI 2-m)(FI 2-m)	OFF / ON	38
	CH (FI 1-m)(FI 1-m)	OFF / ON	96
	CH (FI 1-m)(FI 1-m)	ON / OFF	52
	CH (FI 1-m)(FI 1-m)	OFF / ON	32
	CH (FI 1-m)(FI 1-m)	ON / OFF	78
	CH (FI 1-m)(FI 1-m)	OFF / ON	126
	CH (FI 1-m)(FI 1-m)	ON / ON	41

presentation under the chained FI 2-min FI 2-min schedule or thirty grain presentations under the chained FI 2-min FI 2-min schedule.

Results

Rates and patterns of keypecking within the two components were strongly controlled by the temporal placement of houselight illumination. Figure 1 illustrates the conditions of Experiment One for Bird P-1150. Record A in Fig. 1 shows the pattern of responding maintained under the chained FI 2-min FI 2-min schedule when the houselight was on during both components (ON/ON). Response rates during the first component were characteristically low and irregular. Often, a single response was emitted after the lapse of the 2-min interval. Second component performance was characterized by a moderate rate of responding which either remained constant or gradually increased until food presentation. When the houselight was turned off during the first component and presented simultaneously with the second component (OFF/ON), first-component response rates increased within the first session (Fig. 1, record B). With continued exposure to the OFF/ON condition, first-component response rates were further elevated and became distinctly positively accelerated; second-component patterning similarly became distinctly positively accelerated (Fig. 1, record C).

Figure 1. Sample cumulative records from each condition of Experiment One for P-1150. Unless otherwise indicated, each record was selected from the last twenty sessions of each condition. In all records, the diagonal marks represent completion of the first component schedule and reset of the response pen represents completion of the second component schedule with grain delivery. In this and all subsequent cumulative record figures, the sequence of records from top to bottom corresponds to the order of experimental conditions.


HL COND/COMP
(ON/1st)(ON/2nd)
P-1150
CH(FI 2')(FI 2')
A
(OFF/1st)(ON/2nd) - 1st Sess.
B
(OFF/1st)(ON/2nd)
C
(ON/1st)(OFF/2nd)
D
(OFF/1st)(ON/2nd)- 1st Sess.
E
(OFF/1st)(ON/2nd)
F
(OFF/1st)(OFF/2nd)
G
(ON/1st)(ON/2nd)
H
100 R's
10 MIN

Reversing the placement of houselight illumination within the two components (ON/OFF) resulted in a decrease in first-component response rates, and the continuation of positively accelerated patterning in both components (Fig. 1, record D). Reinstating the OFF/ON condition immediately and chronically elevated first-component response rates (Fig. 1 records E and F) and, as during the previous exposure to this condition, sharp positively accelerated patterns were maintained in both components. Removal of the houselight illumination altogether in the OFF/OFF condition (Fig. 1, record G) resulted in rates and patterns of responding in both components comparable to those during both the ON/ON conditions (Fig. 1, records A and H).

Quantitative summaries of these results are shown in Figure 2. In brief, first-component response rates were comparably low under the ON/ON, ON/OFF, and OFF/OFF conditions. Under the OFF/ON conditions, first-component response rates were as much as six times (or 600%) that of any other arrangement. Quarterlife values for second-component responding were highest when the houselight was illuminated during only one component (OFF/ON and ON/OFF), lowest during the ON/ON condition, and intermediate during the OFF/OFF condition.

Figures 3 and 4 show representative cumulative records from each experimental condition for P-4214 and P-3519, respectively. For both birds, illumination of the houselight throughout both components (ON/ON) resulted in low

Figure 2. Quantitative summaries of keypecks per minute and response quarter-life for each condition of Experiment One for P-1150. Shown are the median session values from the last twenty sessions of each condition. Vertical lines show the interquartile range of values for those sessions. Closed histograms and circles represent component schedules in which the houselight was extinguished, while component schedules in which the houselight was illuminated are represented by open histograms and circles.

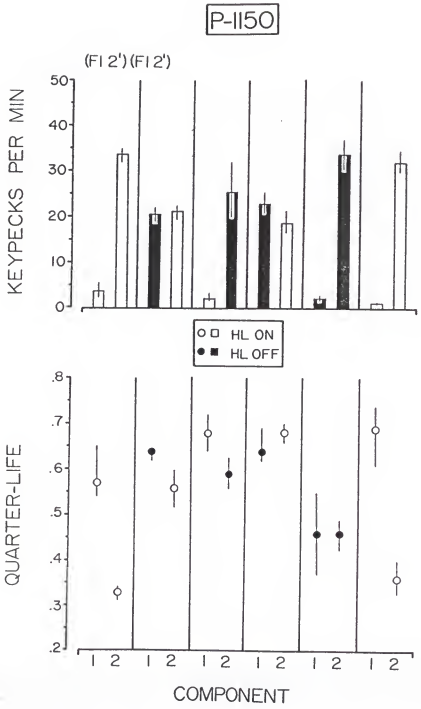

P-1150
(FI 2')(FI 2')
KEYPECKS PER MIN
50
40
30
20
10
0
HL ON
HL OFF
QUARTER-LIFE
.8
.7
.6
.5
.4
.3
.2
1 2 1 2 1 2 1 2 1 2 1 2
COMPONENT

Figure 3. Sample cumulative records from each condition of Experiment One for P-4214. Unless otherwise indicated, each record was selected from the last twenty sessions of each condition. In all records, the diagonal marks represent completion of the first component schedule and reset of the response pen represents completion of the second component schedule with grain delivery.

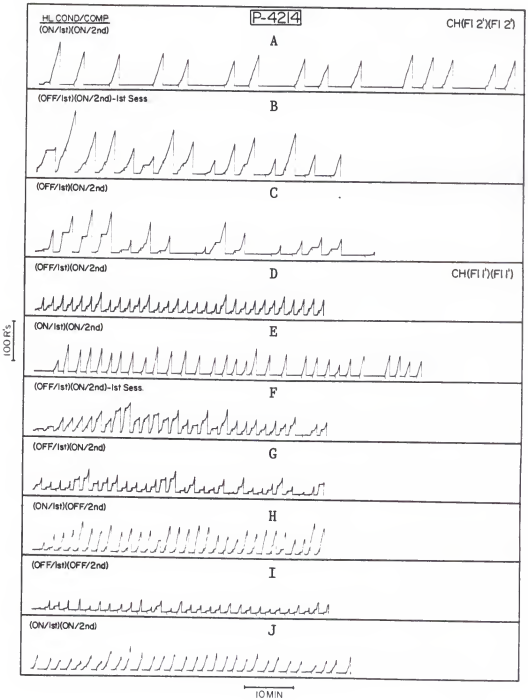
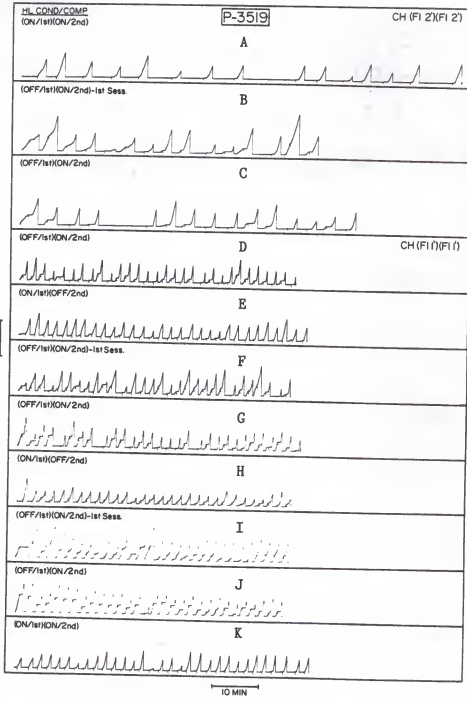

HL COND/COMP
(ON/1st)(ON/2nd)
P-4214
CH(Fl 2')(Fl 2')
A
(OFF/1st)(ON/2nd)-1st Sess.
B
(OFF/1st)(ON/2nd)
C
(OFF/1st)(ON/2nd)
D
CH(Fl l')(Fl l')
(ON/1st)(ON/2nd)
E
100 R's
(OFF/1st)(ON/2nd)-1st Sess.
F
(OFF/1st)(ON/2nd)
G
(ON/1st)(OFF/2nd)
H
(OFF/1st)(OFF/2nd)
I
(ON/1st)(ON/2nd)
J
10 MIN

Figure 4. Sample cumulative records from each condition of Experiment One for P-3519. Unless otherwise indicated, each record was selected from the last twenty sessions of each condition. In all records, the diagonal marks represent completion of the first component schedule and reset of the response pen represents completion of the second component schedule with grain delivery.


HL COND/COMP
(ON/1st)(ON/2nd)
P-3519
CH (F1 2')(F1 2')
A
(OFF/1st)(ON/2nd)-1st Sess.
B
(OFF/1st)(ON/2nd)
C
(OFF/1st)(ON/2nd)
D
CH (F1 1')(F1 1')
(ON/1st)(OFF/2nd)
E
100 FV
(OFF/1st)(ON/2nd)-1st Sess.
F
(OFF/1st)(ON/2nd)
G
(ON/1st)(OFF/2nd)
H
(OFF/1st)(ON/2nd)-1st Sess.
I
(OFF/1st)(ON/2nd)
J
(ON/1st)(ON/2nd)
K
10 MIN

response rates during the first component. Often, responding in the first component consisted of only a single response emitted after the lapse of the two minute interval. Transition to the second component produced a high, constant response rate for P-4214 (Fig. 3, record A), and pausing followed by a high, constant response rate for P-3519 (Fig. 4, record A). Pausing increased and responding became more positively accelerated in the second component for both birds (Figs. 3 and 4, record B) in the first session with the houselight illuminated during only the second component (OFF/ON).

First-component response rates increased for both birds within the initial session of the OFF/ON condition. However, unlike the results with P-1150, this increase in first-component response rates diminished within each session. Typically, each session began with high first-component response rates continuing for approximately one third of the session. By the end of the session, responding maintained during the first component had decreased to those levels occurring under the ON/ON condition (Figs. 3 and 4, record C). In an effort to minimize the tendency for first-component response rates to diminish across the session, the duration of the component schedules was reduced from 2-min to 1-min for both P-4214 and P-3519. The houselight condition remained OFF/ON. Under the chained (FI 1-min) (FI 1-min) schedule, high first-component response rates were maintained throughout the session for both birds

(Figs. 3 and 4, record D). This schedule of food presentation remained in effect for the rest of the experiment for both birds.

When the houselight was illuminated subsequently during both components (ON/ON), pausing increased and response rates decreased substantially during the first component for P-4214 (Fig. 3, record E). First component response rates were comparably low under the ON/OFF and OFF/OFF conditions (Fig. 3, records H and I, respectively). Reinstatement of the OFF/ON condition again produced an immediate high rate of responding during the first component, which was maintained throughout the sessions (Fig. 3, records F and G). As with P-1150, pausing at the onset of the second component was greatest under the OFF/ON conditions and shortest under the ON/ON conditions.

In contrast to the results obtained with P-1150 and P-4214, the first exposure to the ON/OFF condition with P-3519 (Fig. 4, record E) produced first-component response rates comparable to those generated under the preceding OFF/ON condition (Fig. 4, record D). The OFF/ON and ON/OFF conditions were then alternated successively. First-component response rates were elevated immediately during the first session of each OFF/ON condition and increased with each successive exposure to the OFF/ON condition (Fig. 4, records D, F, I). First-component response rates decreased during the second exposure to the ON/OFF condition (Fig. 4, record H). In five of the six possible comparisons

between these two houselight conditions (OFF/ON and ON/OFF), first-component response rates were higher under the OFF/ON condition. Pausing during the second component varied with houselight illumination configuration in a manner similar to that with P-1150 and P-4214.

Quantitative summaries of each of the conditions of Experiment One for P-4214 and P-3519 are shown in Figures 5 and 6, respectively. As with P-1150, first-component response rates were highest for both birds under the OFF/ON conditions. For P-4214, first-component response rates under the OFF/ON conditions were approximately three to six times (300 to 600%) that of any other condition. For P-3519, one exposure to the OFF/ON condition generated response rates during the first component which were more than twice (200%) than under any other condition. Second-component quarterlife values for both birds were lowest under the ON/ON conditions and highest under the OFF/ON conditions.

Discussion

For each pigeon, rate of keypecking during the first component of a two-component chained schedule was increased substantially when the houselight was illuminated during only the second component (OFF/ON). No other configuration of houselight illumination across the two components resulted in the consistent enhancement of response rates

Figure 5. Quantitative summaries of keypecks per minute and response quarter-life for each condition of Experiment One for P-4214. Shown are the median session values from the last twenty sessions of each condition. Vertical lines show the inter-quartile range of values for those sessions. Closed histograms and circles represent component schedules in which the houselight was extinguished, while component schedules in which the houselight was illuminated are represented by open histograms and circles.

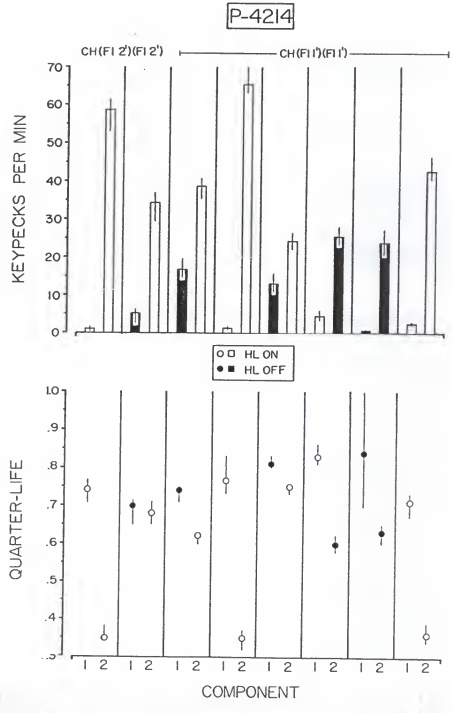
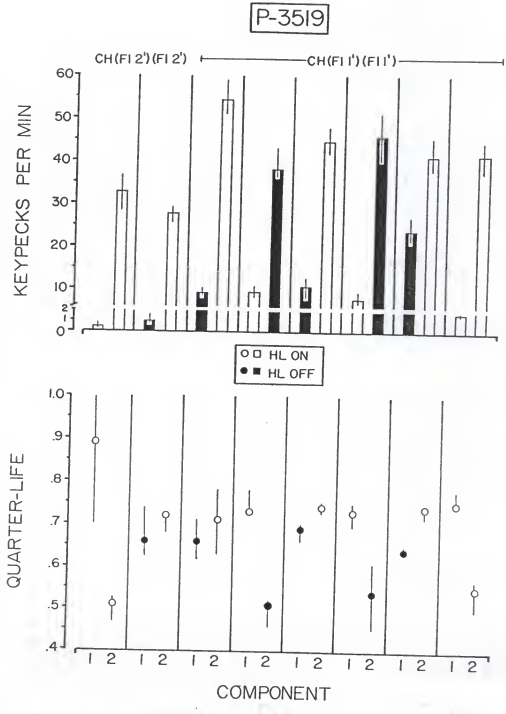

P-4214
CH(FI 2')(FI 2')
CH(FI 1')(FI 1')
KEYPECKS PER MIN
70
60
50
40
30
20
10
0
HL ON
HL OFF
QUARTER-LIFE
1.0
.9
.8
.7
.6
.5
.4
1 2 1 2 1 2 1 2 1 2 1 2 1 2
COMPONENT

Figure 6. Quantitative summaries of keypecks per minute and response quarter-life for each condition of Experiment One for P-3519. Shown are the median session values from the last twenty sessions of each condition. Vertical lines show the interquartile range of values for those sessions. Closed histograms and circles represent component schedules in which the houselight was extinguished, while component schedules in which the houselight was illuminated are represented by open histograms and circles. Note the break in the upper axis.


P-3519
CH(FI 2')(FI 2')
CH(FI 1')(FI 1')
KEYPECKS PER MIN
60
50
40
30
20
10
2
0
HL ON
HL OFF
QUARTER-LIFE
1.0
.9
.8
.7
.6
.5
.4
1 2 1 2 1 2 1 2 1 2 1 2 1 2
COMPONENT

during the first component. Pausing at the beginning of the second component was greatest during the OFF/ON condition and least when the houselight was illuminated throughout both components (ON/ON).

Two suggestions can be offered to account for the increased rate of responding during the first component under the OFF/ON condition: One, changes in houselight illumination may have modified or augmented the existing stimulus control exerted by the component stimuli (i.e., keylight color); Two, the onset of houselight illumination may have functioned to reinforce responding during the first component under the OFF/ON condition. Gollub (1958) reported that response rates during the first component of a two-component chained schedule exceeded those during the first component of a comparable tandem schedule. In the present experiment, the keylight colors associated with the two component schedules may have exerted insufficient stimulus control to generate responding appropriate to the two component schedules independently. That is, the performance generated may have been more characteristic of that maintained under a comparable tandem schedule arrangement. Presentation of houselight illumination during only the second component may have increased the stimulus differences (and the discriminability) between the two components, allowing each to develop and maintain schedule-appropriate performances (i.e., higher response rates during the first component and increased pausing at the beginning of the

second component). However, two aspects of the present results argue against this interpretation. First, the two component schedules controlled diverse rates and patterns of responding prior to any manipulation of houselight illumination. Second, although equal stimulus differences existed between the two components during the OFF/ON and ON/OFF conditions, response rates during the first component were much greater under the OFF/ON configuration.

Rather than augment, the illumination arrangement under the OFF/ON condition may have functioned to modify the stimulus control exerted by keylight color. Discriminative stimuli associated with the first component of a chained schedule not only set the occasion for responding reinforced by the presentation of stimuli correlated with the second component, but are also associated with periods during which primary reinforcement is never presented. As such, these stimuli may acquire aversive or response-suppressive properties. That stimuli paired with periods of low-reinforcement probability can acquire aversive properties is supported by studies in which pigeons and rats respond to terminate or escape from schedules of positive reinforcement (e.g., Azrin, 1961; Thompson, 1964). This escape responding occurs primarily in the immediate postreinforcement period when the probability of further reinforcement is low.

Experiment Two attempted to determine whether the elevation in response rates during the first component under the OFF/ON condition might have resulted from a mitigation

of the response-suppressive properties of the stimuli associated with the first component by the removal of ambient illumination.

CHAPTER THREE

EXPERIMENT TWO

Brown and Jenkins (1968) reported that keypecking by naive, food-deprived pigeons could be generated following several trials in which the response key was illuminated just prior (e.g., eight seconds) to response-independent presentation of food. Because the conditions giving rise to this responding are formally equivalent to certain respondent conditioning procedures (Pavlov, 1927), the keypecking engendered is considered elicited in nature and the illuminated response key is considered an "excitatory" conditioned stimulus. This process is referred to as autoshaping, but may be conceptualized as exemplifying a larger phenomenon termed sign-tracking (Hearst & Jenkins, 1974). Sign-tracking refers to the orientation towards and approach to stimuli associated with an increase in reinforcement frequency, as well as the moving from or avoidance of stimuli associated with a decrease in reinforcement frequency (e.g., Wasserman, Franklin & Hearst, 1974).

Both classes of stimuli are inherent within a two-component chained schedule. Stimuli accompanying the second component are differentially associated with food delivery and should engender pecking; if these stimuli are located

upon the response manipulandum, ongoing keypecking should be augmented by the addition of these elicited pecks (Schwartz & Gamzu, 1977). Conversely, stimuli accompanying the first component are differentially associated with the absence of food presentation and should engender withdrawal or avoidance; if these stimuli are located on the response manipulandum, ongoing keypecking should be suppressed. This interpretation is consistent with the performances generated under the two-component chained schedules employed in Experiment One. Under the ON/ON conditions, low and irregular rates of responding were maintained during the first component. Onset of the second component often produced a burst of keypecking and a high rate of responding was maintained until food presentation. Instatement of the OFF/ON condition, however, resulted in an immediate increase in first-component response rates and increased pausing following the onset of the second component.

It may be conjectured that manipulations in the placement of houselight illumination altered the eliciting capabilities of the component stimuli (i.e., keylight colors), thereby altering the rates and patterns of responding maintained under each component. Wasserman (1973) reported that acquisition of autoshaped keypecking was delayed or eliminated when the chamber houselight was off throughout experimental sessions. It was suggested that keylight illumination, normally localized to the area of the response key by the presence of ambient white houselight illumina-

tion, was diffused throughout the chamber when the houselight was off. Under these conditions, pecking elicited by the association of keylight illumination and food was not directed or localized to the response key, but rather could be directed at any reflective surface within the chamber.

Under the OFF/ON condition of Experiment One, the absence of ambient illumination during the first component allowed the keylight illumination to diffuse throughout the chamber. No longer localizing the keylight stimulus with its response-suppressive properties to the area of the response key may have allowed the rate of keypecking to increase. Additionally, under this houselight-illumination arrangement, both the second component keylight stimulus and the illuminated houselight were differentially associated with food delivery. As such, elicited pecking could be directed at either stimulus, with any pecking directed toward the houselight detracting from the ongoing rate of responding during the second component.

In the present experiment, keylight-color component stimuli were replaced by white geometric shapes projected upon a dark response key. These stimuli are relatively unaffected by illumination conditions. Rates and patterns of keypecking under a two-component chained schedule were then compared during ON/ON and OFF/ON houselight illumination conditions.

Method

Subjects

Pigeons 1150 and 4214 served in Experiment Two.

Apparatus

The apparatus employed in the present experiment was the same as that used in Experiment One.

Procedure

Keypecking was maintained under a two-component chained schedule; (FI 2-min)(FI 2-min) for P-1150 and (FI 1-min)(FI 1-min) for P-4214. A white circle (0) and cross (X) were projected upon the dark response key during the first and second components, respectively. These component stimuli are assumed to be less diffused in the absence of houselight illumination than keylight color. In the absence of houselight illumination, colored keylight illumination is reflected from each wall of the experimental chamber. When the component stimuli are white geometric shapes projected upon the response key, the key illumination available for reflection is similar within each component. Distinctions between the two component stimuli are restricted to the surface of the response key, despite houselight illumination conditions. The order of experimental conditions and the number of sessions within each are shown in Table Two. Sessions terminated following fifteen or thirty grain

Table 2

Summary of the experimental conditions (in order) for Pigeons 1150 and 4214 with the number of sessions under each condition.

Subject	Schedule	Houselight Condition	Number of Sessions
		1st Comp/2nd Comp	
P-1150	CH (FI 2-m)(FI 2-m)	ON / ON	41
	CH (FI 2-m)(FI 2-m)	OFF / ON	31
	CH (FI 2-m)(FI 2-m)	ON / ON	30
P-4214	CH (FI 1-m)(FI 1-m)	ON / ON	30
	CH (FI 1-m)(FI 1-m)	OFF / ON	99
	CH (FI 1-m)(FI 1-m)	OFF / ON	55

presentations for P-1150 and P-4214, respectively. The direct measures, derived measures, and stability criteria employed in the present experiment were the same as those described for Experiment One.

Results

Replacement of keylight color with projected geometric shapes as component stimuli had little effect on performance under the two-component chained schedule. Figures 7 and 8 display sample cumulative records from each condition of Experiment Two for P-1150 and P-4214, respectively. During the ON/ON condition, response rates during the first component were low for both birds. Often only a single response occurred within the first component. Onset of the second component typically generated a burst of responses followed by brief pausing and a constant, moderate rate of responding for P-1150 and a constant, high rate of responding for P-4214 (Figs. 7 and 8, record A).

The instatement of the OFF/ON condition produced an immediate increase in first-component response rates for both birds (Figs. 7 and 8, record B). With further exposure to this condition, first-component response rates were elevated to the levels typically maintained under the second component. Onset of the second component occasioned a substantial pause for both pigeons followed by a moderate and accelerating response rate for P-1150 and a high,

Figure 7. Sample cumulative records from each condition of Experiment Two for P-1150. Unless otherwise indicated, each record was selected from the last twenty sessions of each condition. In all records, the diagonal marks represent completion of the first component schedule and reset of the response pen represents completion of the second component schedule with grain delivery.

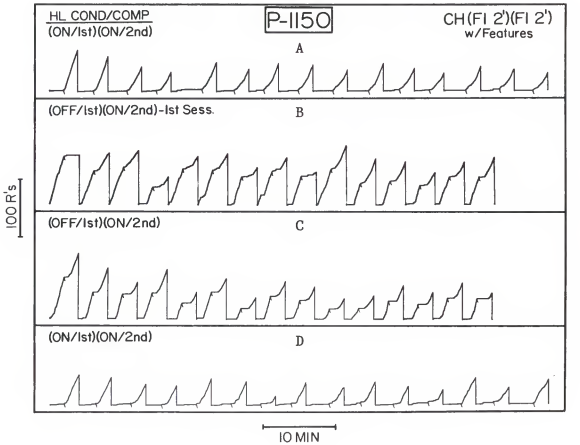
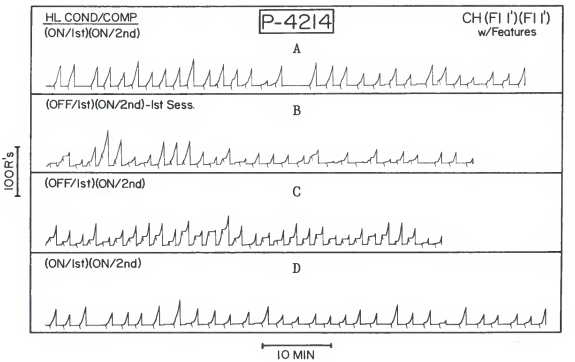

HL COND/COMP
(ON/1st)(ON/2nd)
P-1150
CH(FI 2')(FI 2')
w/Features
A
(OFF/1st)(ON/2nd)-1st Sess.
B
100 R's
(OFF/1st)(ON/2nd)
C
(ON/1st)(ON/2nd)
D
10 MIN

Figure 8. Sample cumulative records from each condition of Experiment Two for P-4214. Unless otherwise indicated, each record was selected from the last twenty sessions of each condition. In all records, the diagonal marks represent completion of the first component schedule and reset of the response pen represents completion of the second component schedule with grain delivery.


HL COND/COMP
(ON/1st)(ON/2nd)
P-4214
CH (Fl l')(Fl l')
w/Features
A
(OFF/1st)(ON/2nd)-1st Sess.
B
100 R's
(OFF/1st)(ON/2nd)
C
(ON/1st)(ON/2nd)
D
10 MIN

constant response rate for P-4214 (Figs. 7 and 8, record C). Casual observation of both birds during this pause revealed orientation to and pecking at the illuminated houselight. Reinstatement of the ON/ON condition generated responding similar to that during the previous exposure to this condition (Figs. 7 and 8, record D).

Quantitative summaries for P-1150 and P-4214 of each condition of Experiment Two are shown in Figures 9 and 10, respectively. Response rates during the first component under the OFF/ON condition were approximately 9 times (900%) and 4 times (400%) that under the ON/ON conditions for P-1150 and P-4214, respectively. Values for response quarter-life during the second component changed in a similar manner to that observed in Experiment One; quarter-life values were lowest under the ON/ON condition and increased substantially under the OFF/ON condition.

Discussion

Despite the employment of component stimuli which are less diffused in the absence of ambient illumination, first-component response rates were enhanced under the OFF/ON condition of the present experiment in a manner comparable to that observed in Experiment One. Thus, localization or diffusion of component stimuli by the presence or absence of ambient illumination would not appear responsible for the elevation in first-component response rates under the OFF/ON

Figure 9. Quantitative summaries of keypecks per minute and response quarter-life for each condition of Experiment Two for P-1150. Shown are the median session values from the last twenty sessions of each condition. Vertical lines show the inter-quartile range of values for those sessions. Closed histograms and circles represent component schedules in which the houselight was extinguished, while component schedules in which the houselight was illuminated are represented by open histograms and circles.

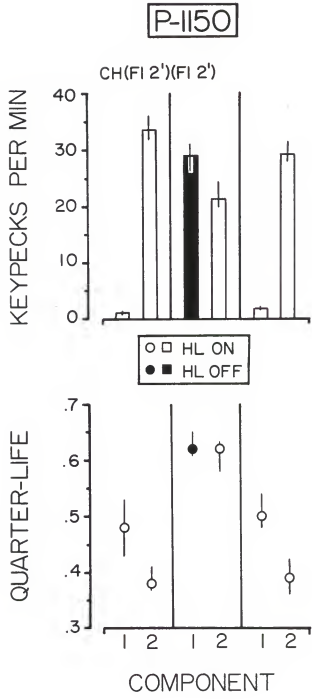
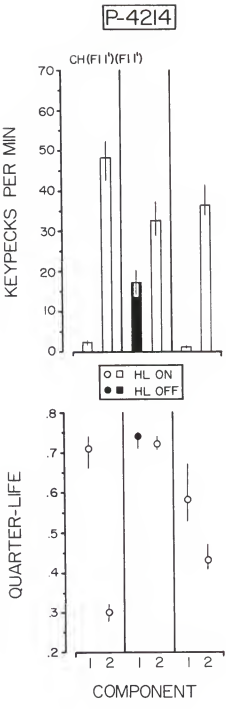

P-1150
CH(FI 2')(FI 2')
KEYPECKS PER MIN
40
30
20
10
0
HL ON
HL OFF
QUARTER-LIFE
.7
.6
.5
.4
.3
1 2 1 2 1 2
COMPONENT

Figure 10. Quantitative summaries of keypecks per minute and response quarter-life for each condition of Experiment Two for P-4214. Shown are the median session values from the last twenty sessions of each condition. Vertical lines show the interquartile range of values for those sessions. Closed histograms and circles represent component schedules in which the houselight was extinguished, while component schedules in which the houselight was illuminated are represented by open histograms and circles.


P-4214
CH(FI I')(FI I')
KEYPECKS PER MIN
70
60
50
40
30
20
10
0
HL ON
HL OFF
QUARTER-LIFE
.8
.7
.6
.5
.4
.3
.2
1 2 1 2 1 2
COMPONENT

condition. Two additional results support the above conclusion.

First, response rates during the first component were not enhanced in Experiment One under the OFF/OFF condition. First-component response rates remained low even though keylight colors, which were diffused throughout the chamber in the absence of ambient illumination, were used as component stimuli. Similarly, Robinson and Shelley (1974) reported that response rates maintained under interval schedules were lowered rather than increased in the absence of chamber illumination. Second, Galbicka (1981) compared keypeck rates during the first components of chained schedules in which the component stimuli were located either on the response key or on a second, nonoperative signal key (Keller, 1974). Under the latter condition, any response-suppressive properties of the stimuli associated with the first component should have been displaced to the signal key, thus allowing a higher rate of responding on the operative response key. However, no consistent differences in the performances during the first component of the two chained schedule forms were observed. Together these results suggest that the increased rate of responding during the first component under the OFF/ON condition does not represent a modification of some inhibitory process inherent within the chained schedule. Rather, this increase in response rates would appear to be a direct function of the contingent onset of houselight illumination.

Previous studies have demonstrated that changes in illumination can function as unconditioned reinforcement (Kish, 1966). However, these demonstrations and the present experiments differ along several dimensions including species and procedures employed, as well as the magnitude of the rate enhancement observed. The elevations in first-component response rates under the OFF/ON conditions of Experiments One and Two were many times the rate of responding maintained when changes in illumination are the only scheduled consequences for responding (e.g., Stewart, 1960). The increase in first-component response rates under the OFF/ON conditions are similar in magnitude to the increase in first-component response rates when a food-paired stimulus is interpolated between components during a two-component chained schedule of food presentation (Malagodi et al., 1973). This similarity suggests that any possible reinforcing properties of houselight illumination might be derived through association with some aspect of food presentation. Experiments Three and Four assessed two possible sources of the reinforcing properties of houselight illumination.

CHAPTER FOUR

EXPERIMENT THREE

In Experiments One and Two, the presentation of houselight illumination at the completion of the first component may have functioned to reinforce responding as a result of the temporal proximity of illumination to food presentation at the end of the second component. Stimuli associated with the terminal component of a chained schedule arrangement are present immediately prior to the presentation of primary reinforcement and, under most conceptualizations regarding the formation of secondary or conditioned reinforcers, this temporal contiguity is sufficient to imbue the terminal component stimuli with reinforcing properties (e.g., Gollub, 1977; Kelleher, 1966b; Kelleher & Gollub, 1962; Marr, 1969). Three main classes of manipulations have been employed to assess the reinforcing properties of stimuli associated with the terminal component of chained schedules; changes in the order of presentation of component stimuli (e.g., Byrd, 1971; Ferster & Skinner, 1957; Jwaideh, 1973; Kelleher & Fry, 1962), alterations in the rate or probability of reinforcement in the terminal component

(e.g. Autor, 1960, 1969; Ferster & Skinner, 1957; Baron, 1969), and brief presentation of the terminal component stimulus during other component schedules (Marr, 1969).

In brief, this research has shown that schedule-appropriate patterns of responding are maintained by an established terminal component stimulus regardless of its altered order within a chained schedule (e.g., Byrd, 1971; Ferster & Skinner, 1957, Jwaideh, 1973; Kelleher & Fry, 1962), that the reinforcing strength of the terminal component stimulus is related directly to the rate or probability of reinforcement in its presence (e.g., Autor, 1960, 1969; Ferster & Skinner, 1957; Findley, 1954, 1962; Hanson & Witoslawski, 1958; Herrnstein, 1961, 1964; Kaufman & Baron, 1969), and that contingent brief presentations of terminal component stimuli within other components of a chained schedule can increase the ongoing rate of responding in those component schedules (Marr, 1969).

In sum, these data would support the suggestion that the temporal arrangement of houselight illumination under the OFF/ON conditions of Experiments One and Two could establish illumination as a conditioned reinforcer for responding during the first component. Experiment Three employed a three-component chained schedule to compare the effects of contingent houselight illumination under conditions in which illumination was and was not associated with the terminal component.

Method

Subjects

Three adult male White Carneaux pigeons (P-1150, P-2225, and P-3775) were maintained at 80% of their free-feeding weights. Each had previous exposure to simple schedules of reinforcement. Pigeon 1150 had served in Experiments One and Two. Each pigeon was individually housed with water and health grit continuously available and under the same illumination conditions described in Experiment One.

Apparatus

The apparatus employed was the same as that in Experiments One and Two. Keylight colors again served as component stimuli.

Procedure

Throughout Experiment Three keypecking was maintained under a three-component chained schedule of food presentation; chained (FI 2-min)(FI 2-min)(FI 2-min) for P-1150 and chained (FI 1-min)(FI 1-min)(FI 1-min) for Pigeons 2225 and 3775. During the first component the response key was illuminated blue and during the second and third components the response key was illuminated yellow and red, respectively. The presence of houselight illumination in each of the components was manipulated across experimental

conditions. The order of experimental conditions and the number of sessions under each are shown in Table Three. Sessions terminated following the completion of ten grain presentations for P-1150 and twenty grain presentations for Pigeons 2225 and 3775. Total duration and number of responses were recorded by component within each session. From these measures, average component response rates were derived for each session. All other procedural aspects were identical to those described in Experiments One and Two.

Results

Performances typical of three-component chained schedules (Kelleher & Gollub, 1962) developed for each pigeon in Experiment Three. Representative cumulative records from each experimental condition are shown in Figures 11, 12, and 13 for Pigeons 1150, 2225, and 3775, respectively. With the houselight illuminated throughout each component (ON/ON/ON), first-component response rates characteristically were low, second-component responses rates were moderate, and response rates during the third component were constant and high for P-1150 (Fig. 11, record A). For both P-2225 and P-3775, response rates during the first component also were low, but second-component response rates were high and constant. Responding in the third component was characterized by a pause followed by positively accelerated response rates until food presentation. The average response rate in the

Table 3

Summary of the experimental conditions (in order) for Pigeons 1150, 2225, and 3775 with the number of sessions under each condition.

Subject	Schedule	Houselight Condition	Number of Sessions
		1st Comp/2nd Comp	
P-1150			
	CH (FI 2-m)(FI 2-m)(FI 2-m)	ON / ON / ON	38
	CH (FI 2-m)(FI 2-m)(FI 2-m)	OFF / ON / ON	30
	CH (FI 2-m)(FI 2-m)(FI 2-m)	OFF / ON / OFF	48
	CH (FI 2-m)(FI 2-m)(FI 2-m)	OFF / OFF / ON	46
	CH (FI 2-m)(FI 2-m)(FI 2-m)	ON / ON / ON	55
P-4214			
	CH (FI 1-m)(FI 1-m)(FI 1-m)	ON / ON / ON	50
	CH (FI 1-m)(FI 1-m)(FI 1-m)	OFF / ON / ON	158
	CH (FI 1-m)(FI 1-m)(FI 1-m)	OFF / OFF / ON	63
	CH (FI 1-m)(FI 1-m)(FI 1-m)	OFF / ON / OFF	50
	CH (FI 1-m)(FI 1-m)(FI 1-m)	ON / ON / ON	117
P-3519			
	CH (FI 1-m)(FI 1-m)(FI 1-m)	ON / ON / ON	42
	CH (FI 1-m)(FI 1-m)(FI 1-m)	OFF / ON / ON	38
	CH (FI 1-m)(FI 1-m)(FI 1-m)	OFF / OFF / ON	96
	CH (FI 1-m)(FI 1-m)(FI 1-m)	OFF / ON / OFF	32
	CH (FI 1-m)(FI 1-m)(FI 1-m)	ON / ON / ON	78

Figure 11. Sample cumulative records from each condition of Experiment Three for P-1150. Unless otherwise indicated, each record was selected from the last twenty sessions of each condition. In all records, the diagonal marks represent completion of the first and second component schedules and reset of the response pen represents completion of the third component schedule with grain delivery.

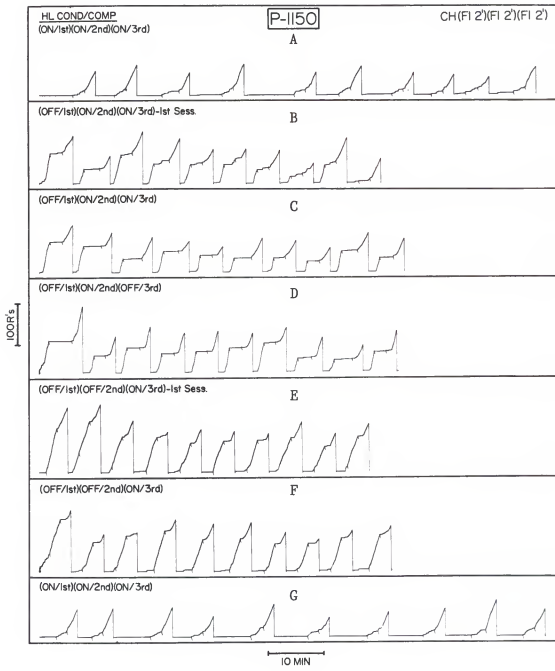

HL COND/COMP
(ON/1st)(ON/2nd)(ON/3rd)
P-1150
CH(FI 2')(FI 2')(FI 2')
A
(OFF/1st)(ON/2nd)(ON/3rd)-1st Sess.
B
(OFF/1st)(ON/2nd)(ON/3rd)
C
(OFF/1st)(ON/2nd)(OFF/3rd)
D
100R's
(OFF/1st)(OFF/2nd)(ON/3rd)-1st Sess.
E
(OFF/1st)(OFF/2nd)(ON/3rd)
F
(ON/1st)(ON/2nd)(ON/3rd)
G
10 MIN

Figure 12. Sample cumulative records from each condition of Experiment Three for P-2225. Unless otherwise indicated, each record was selected from the last twenty sessions of each condition. In all records, the diagonal marks represent completion of the first and second component schedules and reset of the response pen represents completion of the third component schedule with grain delivery.

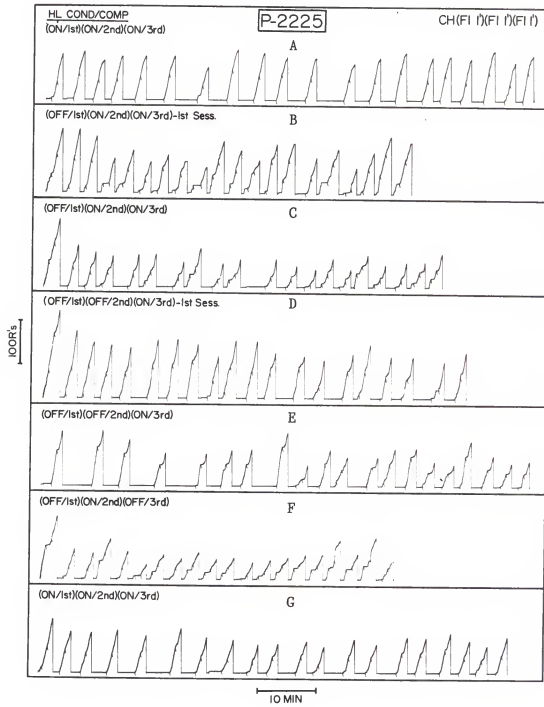
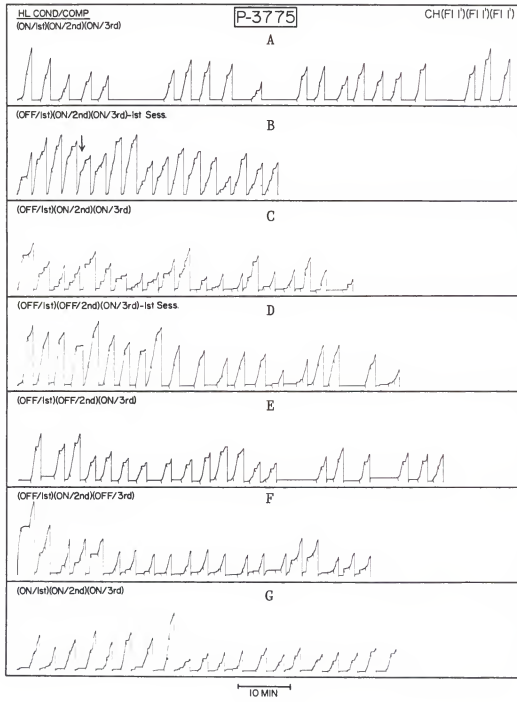

HL COND/COMP
(ON/1st)(ON/2nd)(ON/3rd)
P-2225
CH(F1 1')(F1 1')(F1 1')
A
(OFF/1st)(ON/2nd)(ON/3rd)-1st Sess.
B
(OFF/1st)(ON/2nd)(ON/3rd)
C
(OFF/1st)(OFF/2nd)(ON/3rd)-1st Sess.
D
100R's
(OFF/1st)(OFF/2nd)(ON/3rd)
E
(OFF/1st)(ON/2nd)(OFF/3rd)
F
(ON/1st)(ON/2nd)(ON/3rd)
G
10 MIN

Figure 13. Sample cumulative records from each condition of Experiment Three for P-3775. Unless otherwise indicated, each record was selected from the last twenty sessions of each condition. In all records, the diagonal marks represent completion of the first and second component schedules and reset of the response pen represents completion of the third component schedule with grain delivery. The arrow in the second record from the top indicates the area of a recorder malfunction resulting in the omission of three chained schedule completions.


HL COND/COMP
(ON/1st)(ON/2nd)(ON/3rd)
P-3775
CH(FI I')(FI I')(FI I')
A
(OFF/1st)(ON/2nd)(ON/3rd)-1st Sess.
B
(OFF/1st)(ON/2nd)(ON/3rd)
C
(OFF/1st)(OFF/2nd)(ON/3rd)-1st Sess.
D
100R's
(OFF/1st)(OFF/2nd)(ON/3rd)
E
(OFF/1st)(ON/2nd)(OFF/3rd)
F
(ON/1st)(ON/2nd)(ON/3rd)
G
10 MIN

third component was lower than that under the second component for both birds (Figs. 12 and 13, record A).

When the houselight was illuminated during only the second and third components (OFF/ON/ON), response rates during the first component increased dramatically. For each pigeon, this rate enhancement was evident in the first session (Figs. 11, 12, and 13, record B) and was sustained throughout the exposure to this condition (Figs. 11, 12, and 13, record C). Second component response rates were substantially reduced, with performances characterized by pausing followed by positively accelerated responding until the onset of the third component. First-component response rates remained elevated when the houselight was illuminated in only the second component (OFF/ON/OFF). Even though houselight illumination was no longer present during the third component, first-component response rates were the highest observed for Pigeons 1150 and 2225, and comparable to those under the OFF/ON/ON condition for P-3775. Second-component response rates were comparable to those under the OFF/ON/ON condition for P-1150 and were substantially reduced from those levels for Pigeons 2225 and 3375 (Fig. 11, record D; Figs. 12 and 13, record F).

Illumination of the houselight during only the third component (OFF/OFF/ON) generated the highest second-component response rates observed for P-1150 (Fig. 11, records E and F); the second-component response rates for Pigeons 2225 and 3775 were comparable to those under the

ON/ON/ON condition (Figs. 12 and 13, records D and E). Finally, the reinstatement of the ON/ON/ON condition produced responding generally similar to that obtained under the previous exposure, with the exception that response rates during the third component now exceeded those during the second component for P-2225 (Figs. 11, 12, and 13, records G).

Figures 14, 15, and 16 show quantitative summaries from each condition of Experiment Three for Pigeons 1150, 2225, and 3775, respectively. The contingent onset of houselight illumination during the second component enhanced first-component response from 4 to 20 times (400 to 2000%) that under the ON/ON/ON condition, whether or not the illumination was associated with the third component.

Discussion

As in Experiments One and Two, response rates in the first component of a chained schedule were considerably enhanced when the chamber houselight was illuminated at the onset of the second component. These results expand the generality of the two previous experiments to an extended chained schedule arrangement. Additionally, the rate-enhancing effects of contingent houselight illumination were sustained regardless of whether or not the houselight was illuminated during the third component. These results support the earlier suggestion that contingent houselight

Figure 14. Quantitative summaries of keypecks per minute for each condition of Experiment Three for P-1150. Shown are the median session values from the last twenty sessions of each condition. Vertical lines show the interquartile range of values for those sessions. Closed histograms represent component schedules in which the houselight was extinguished, while component schedules in which the houselight was illuminated are represented by open histograms.

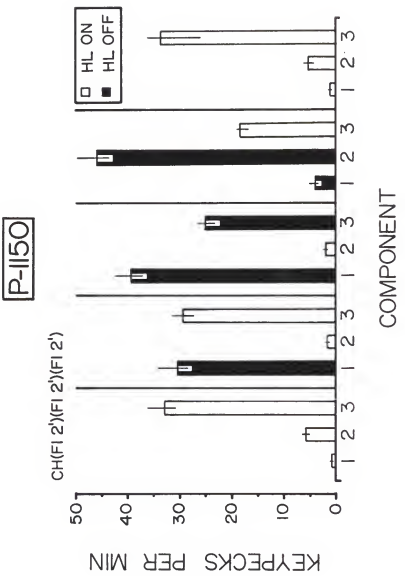

P-1150
CH(FI 2')(FI 2')(FI 2')
HL ON
HL OFF
KEYPECKS PER MIN
0
10
20
30
40
50
1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3
COMPONENT

Figure 15. Quantitative summaries of keypecks per minute for each condition of Experiment Three for P-2225. Shown are the median session values from the last twenty sessions of each condition. Vertical lines show the interquartile range of values for those sessions. Closed histograms represent component schedules in which the houselight was extinguished, while component schedules in which the houselight was illuminated are represented by open histograms.

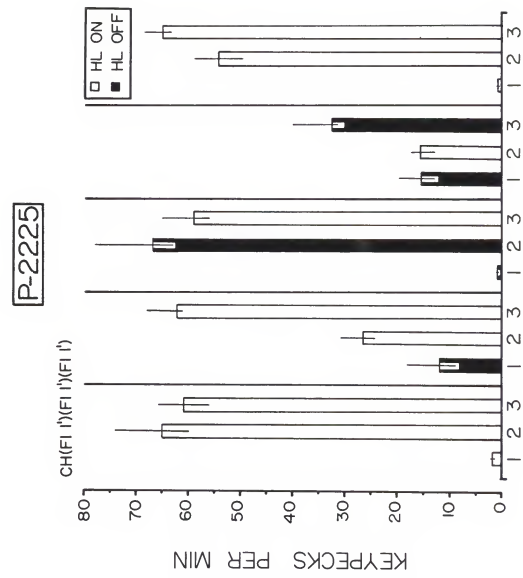
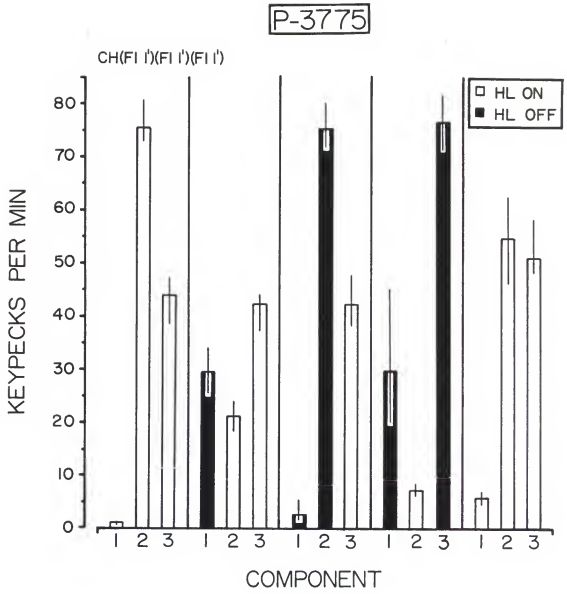

P-2225
CH(FI I')(FI I')(FI I')
HL ON
HL OFF
KEYPECKS PER MIN
0
10
20
30
40
50
60
70
80
1 2 3 1 2 3 1 2 3 1 2 3
COMPONENT

Figure 16. Quantitative summaries of keypecks per minute for each condition of Experiment Three for P-3775. Shown are the median session values from the last twenty sessions of each condition. Vertical lines show the interquartile range of values for those sessions. Closed histograms represent component schedules in which the houselight was extinguished, while component schedules in which the houselight was illuminated are represented by open histograms.


P-3775
CH(FI I')(FI I')(FI I')
HL ON
HL OFF
KEYPECKS PER MIN
0
10
20
30
40
50
60
70
80
1 2 3 1 2 3 1 2 3 1 2 3 1 2 3
COMPONENT

illumination may function as a reinforcing stimulus. They do not support the interpretation that the rate-enhancing effects of illumination onset are the result of the direct and chronic association of the illuminated houselight with the terminal component. It may be argued that the enhancement of first-component response rates under the OFF/ON/OFF condition represents the lingering reinforcing properties acquired by the illuminated houselight through previous association with the third component. However, the large number of sessions conducted under the OFF/ON/OFF condition (from 50 to 87) without decreases in first-component response rates would argue against this interpretation.

That second-component response rates for P-2225 and P-3775 were not enhanced during the OFF/OFF/ON condition from those under the preceding ON/ON/ON condition may have been related to the high ongoing response rates maintained by these component schedules. For both birds, second-component response rates exceeded third-component response rates under the initial exposure to the ON/ON/ON condition. For P-1150, second-component response rates under the ON/ON/ON condition were considerably lower than those maintained during the third component and were significantly enhanced under the OFF/OFF/ON condition. Established reinforcing stimuli made contingent on high-rate behaviors do not always enhance response rates and may lower them (e.g., Skinner & Morse, 1958). In addition, there is a growing body of evidence that suggests that ongoing rate of

responding is one of several important determinants of not only reinforcement and punishment (Morse & Kelleher, 1977), but also the effects of a variety of independent variables such as psychoactive agents (Kelleher & Morse, 1968).

CHAPTER FIVE

EXPERIMENT FOUR

The stimulus most tightly correlated with food presentation in most operant experimental arrangements is the illumination of the food hopper. With pigeons as subjects, food presentation generally is accompanied by the offset of keylight and houselight illumination, and by direct illumination of the feeder tray. Thus, feederlight illumination immediately precedes and coincides with eating from the tray. Within most conceptualizations of conditioned reinforcement, this temporal arrangement of feederlight illumination and food presentation is considered sufficient to establish the feeder light as a conditioned reinforcer (e.g., Gollub, 1977; Kelleher, 1966a; Kelleher & Gollub, 1962; Marr, 1969).

Numerous studies have demonstrated the reinforcing properties of contingent feederlight illumination (e.g. de Lorge, 1971; Findley & Brady, 1965; Malagodi et al., 1973). Findley and Brady (1965) reported both a dramatic decrease in pre-ratio pausing and increase in overall response rates by a chimpanzee responding under a fixed-ratio (FR) 4000 schedule of food delivery when each 400th response resulted in the brief illumination of the feeder. Similarly, the

brief illumination of the feederlight interpolated between component stimuli in a two-component chained schedule generated first-component response rates by pigeons comparable to those obtained when food was presented at the completion of each component (Malagodi et al., 1973).

Throughout Experiments One through Three both the houselight and feederlight illuminations were white and relatively intense. Generalization between the two sources of illumination may have been responsible for the apparent reinforcing characteristics of houselight illumination. Experiment Four assesses this possibility by manipulating the presence of houselight illumination once the similarities between houselight and feederlight illumination have been decreased.

Method

Subjects

The subjects were the same as in Experiment Three.

Apparatus

The apparatus employed was the same as that in Experiment Three except that a 1.4W light was mounted above the feeder and covered with a green translucent cap.

Procedure

The chained schedule and keylight stimuli used were the same as in Experiment Three. The present experiment consisted of three phases: (1) the houselight illuminated during each component (ON/ON/ON) and the feeder illuminated green during grain presentation and white between grain presentations, (2) the houselight illuminated during only the second and third component (OFF/ON/ON) and the feederlight conditions the same as in (1) above, and (3) continuance of the OFF/ON/ON condition and the feeder not illuminated between grain presentations. The order of experimental conditions and the number of sessions under each are shown in Table 4. All other procedural aspects were identical to those described in Experiment Three.

Results

Despite the change in feederlight conditions, rates and patterns of responding typical of three-component chained schedules were developed and maintained under the ON/ON/ON condition. Representative cumulative records from each condition of Experiment Four are displayed in Figures 17, 18, and 19 for Pigeons 1150, 2225, and 3775, respectively. The lowered overall response rates for P-2225 represent the only significant change in performance from that under the ON/ON/ON condition of Experiment Three (Figs. 17, 18, and 19, record A).

Table 4

Summary of the experimental conditions (in order) for Pigeons 1150, 2225, and 3775 with the number of sessions under each condition.

Subject	Schedule	Houselight Condition / Feederlight Condition 1st Comp/2nd Comp/ 3rd Comp	Number of Sessions
P-1150			
CH	(FI 2-m)(FI 2-m)(FI 2-m)	ON / ON / ON Grn fdr illum-rein. Wht fdr illum-interrein.	59
CH	(FI 2-m)(FI 2-m)(FI 2-m)	OFF / ON / ON Grn fdr illum-rein. Wht fdr illum-interrein.	53
CH	(FI 2-m)(FI 2-m)(FI 2-m)	OFF / ON / ON Grn fdr illum-rein.	26
P-2225			
CH	(FI 1-m)(FI 1-m)(FI 1-m)	ON / ON / ON Grn fdr illum-rein. Wht fdr illum-interrein.	51
CH	(FI 1-m)(FI 1-m)(FI 1-m)	OFF / ON / ON Grn fdr illum-rein. Wht fdr illum-interrein.	53
CH	(FI 1-m)(FI 1-m)(FI 1-m)	OFF / ON / ON Grn fdr illum-rein.	32
P-3775			
CH	(FI 1-m)(FI 1-m)(FI 1-m)	ON / ON / ON Grn fdr illum-rein. Wht fdr illum-interrein.	66
CH	(FI 1-m)(FI 1-m)(FI 1-m)	OFF / ON / ON Grn fdr illum-rein. Wht fdr illum-interrein.	46
CH	(FI 1-m)(FI 1-m)(FI 1-m)	OFF / ON / ON Grn fdr illum-rein.	27

Figure 17. Sample cumulative records from each condition of Experiment Four for P-1150. Unless otherwise indicated, each record was selected from the last twenty sessions of each condition. In all records, the diagonal marks represent completion of the first and second component schedules and reset of the response pen represents completion of the third component schedule with grain delivery.

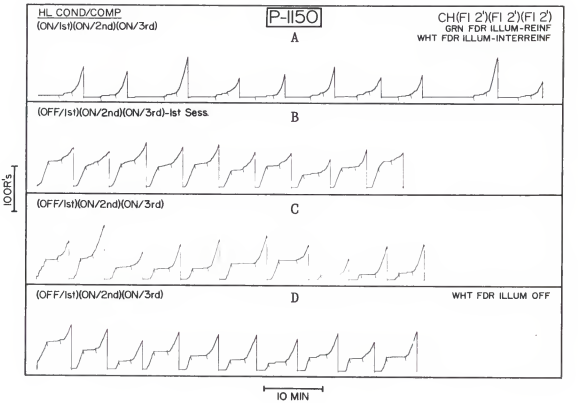

HL COND/COMP
(ON/1st)(ON/2nd)(ON/3rd)
P-1150
A
CH(FI 2')(FI 2')(FI 2')
GRN FDR ILLUM-REINF
WHT FDR ILLUM-INTERREINF
(OFF/1st)(ON/2nd)(ON/3rd)-1st Sess.
B
100R's
(OFF/1st)(ON/2nd)(ON/3rd)
C
(OFF/1st)(ON/2nd)(ON/3rd)
D
WHT FDR ILLUM OFF
10 MIN

Figure 18. Sample cumulative records from each condition of Experiment Four for P-2225. Unless otherwise indicated, each record was selected from the last twenty sessions of each condition. In all records, the diagonal marks represent completion of the first and second component schedules and reset of the response pen represents completion of the third component schedule with grain delivery.

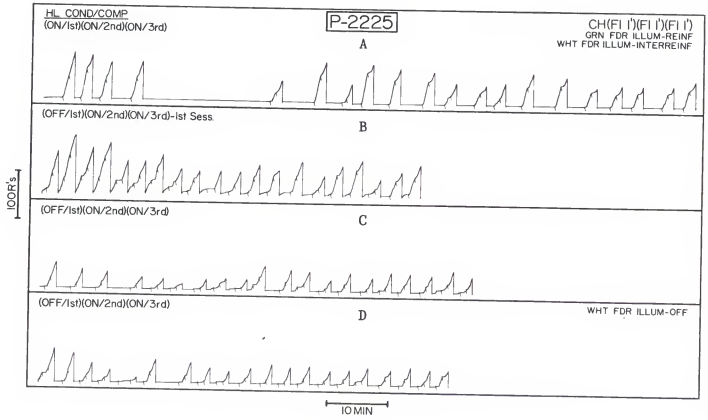
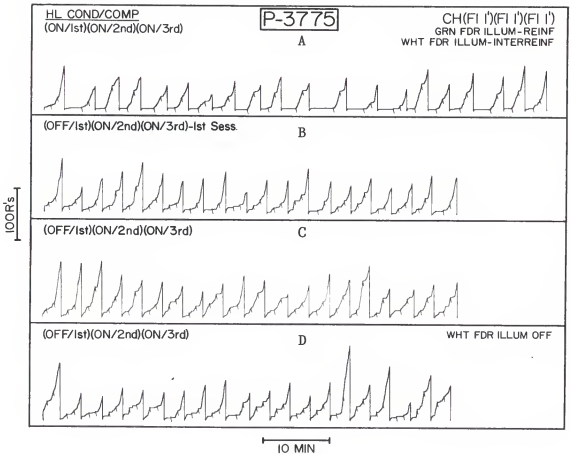

HL COND/COMP
(ON/1st)(ON/2nd)(ON/3rd)
P-2225
A
CH(FI I')(FI I')(FI I')
GRN FDR ILLUM-REINF
WHT FDR ILLUM-INTERREINF
(OFF/1st)(ON/2nd)(ON/3rd)-1st Sess.
B
100R's
(OFF/1st)(ON/2nd)(ON/3rd)
C
(OFF/1st)(ON/2nd)(ON/3rd)
D
WHT FDR ILLUM-OFF
10 MIN

Figure 19. Sample cumulative records from each condition of Experiment Four for P-3775. Unless otherwise indicated, each record was selected from the last twenty sessions of each condition. In all records, the diagonal marks represent completion of the first and second component schedules and reset of the response pen represents completion of the third component schedule with grain delivery.


HL COND/COMP
(ON/1st)(ON/2nd)(ON/3rd)
P-3775
A
CH(FI I')(FI I')(FI I')
GRN FDR ILLUM-REINF
WHT FDR ILLUM-INTERREINF
(OFF/1st)(ON/2nd)(ON/3rd)-1st Sess.
B
100R's
(OFF/1st)(ON/2nd)(ON/3rd)
C
(OFF/1st)(ON/2nd)(ON/3rd)
D
WHT FDR ILLUM OFF
10 MIN

When the houselight was illuminated during only the second and third components (OFF/ON/ON), first-component response rates were elevated within the initial session (Figs. 17, 18, and 19, record B). First-component response rates remained elevated throughout the condition. Response rates in the second component were reduced for each bird with the development of pausing and positively accelerated responding for P-2225 and P-3775 (Figs. 17, 18, and 19, record C). Removal of the white feederlight illumination between grain presentations had no consistent effect on responding (Figs. 17, 18, and 19, record D).

Quantitative summaries for each condition of Experiment Four are shown in Figures 20, 21, and 22 for Pigeons 1150, 2225, and 3775, respectively. Since no systematic change in responding accompanied the removal of the white feederlight illumination between grain presentations,response rates from the two OFF/ON/ON conditions can be considered together. First component response rates under the OFF/ON/ON conditions ranged from approximately 5 to 70 times (500 to 7000%) that under the ON/ON/ON condition.

Discussion

The present experiment examined the possibility that the putative reinforcing properties of houselight illumination demonstrated in the preceding three experiments were the result of stimulus generalization from the feederlight

Figure 20. Quantitative summaries of keypecks per minute for each condition of Experiment Four for P-1150. Shown are the median session values from the last twenty sessions of each condition. Vertical lines show the interquartile range of values for those sessions. Closed histograms represent component schedules in which the houselight was extinguished, while component schedules in which the houselight was illuminated are represented by open histograms. In sections A and B, the feeder was illuminated green during grain deliveries and white between grain deliveries. In section C the white feederlight was extinguished. Note the break in the axis.

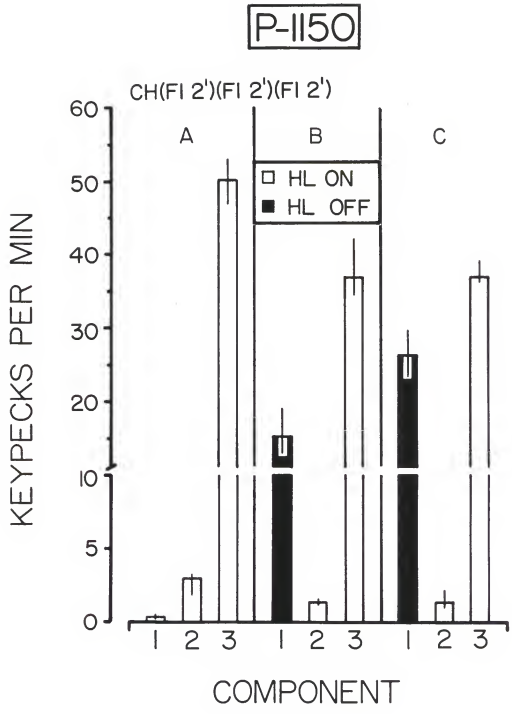

P-1150
CH(FI 2')(FI 2')(FI 2')
A
B
C
HL ON
HL OFF
KEYPECKS PER MIN
60
50
40
30
20
10
5
0
1 2 3 1 2 3 1 2 3
COMPONENT

Figure 21. Quantitative summaries of keypecks per minute for each condition of Experiment Four for P-2225. Shown are the median session values from the last twenty sessions of each condition. Vertical lines show the interquartile range of values for those sessions. Closed histograms represent component schedules in which the houselight was extinguished, while component schedules in which the houselight was illuminated are represented by open histograms. In sections A and B, the feeder was illuminated green during grain deliveries and white between grain deliveries. In section C the white feederlight was extinguished. Note the break in the axis.

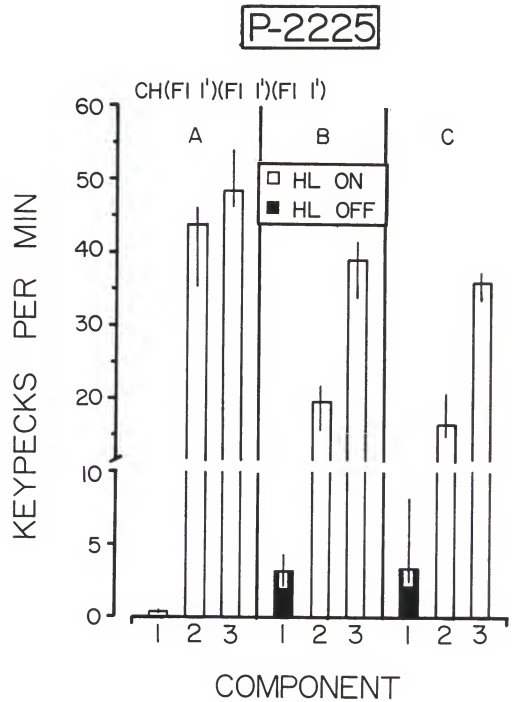
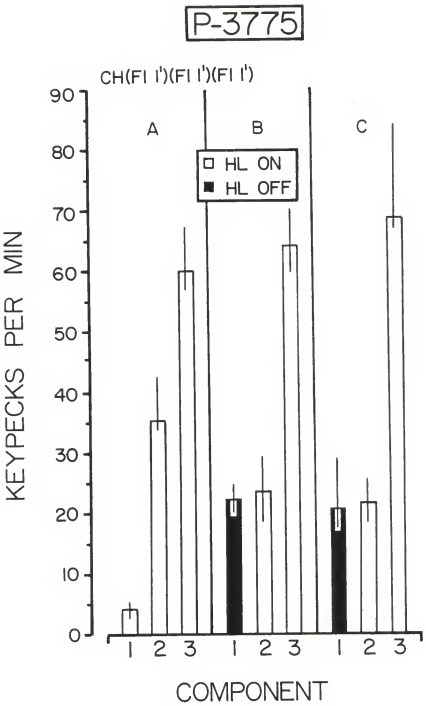

P-2225
CH(FI I')(FI I')(FI I')
A
B
C
HL ON
HL OFF
KEYPECKS PER MIN
60
50
40
30
20
10
5
0
1
2
3
1
2
3
1
2
3
COMPONENT

Figure 22. Quantitative summaries of keypecks per minute for each condition of Experiment Four for P-3775. Shown are the median session values from the last twenty sessions of each condition. Vertical lines show the interquartile range of values for those sessions. Closed histograms represent component schedules in which the houselight was extinguished, while component schedules in which the houselight was illuminated are represented by open histograms. In sections A and B, the feeder was illuminated green during grain deliveries and white between grain deliveries. In section C the white feederlight was extinguished.


P-3775
CH(FI I')(FI I')(FI I')
A
B
C
HL ON
HL OFF
KEYPECKS PER MIN
90
80
70
60
50
40
30
20
10
0
1 2 3 1 2 3 1 2 3
COMPONENT

illumination present during grain presentation. This was accomplished by changing the feederlight illumination during grain presentation from white to green while presenting the white feederlight throughout the interreinforcement period. These two changes were made to (1) reduce the similarity between houselight and feederlight illumination, and (2) to associate the white feederlight with periods of nonreinforcement to reduce or eliminate any existing conditioned reinforcing characteristics maintained by white illumination.

Although contingent feederlight illumination has repeatedly been shown to function as a potent conditioned reinforcer (e.g., Findley & Brady, 1965; Malagodi et al., 1973), generalization from the feederlight to houselight illumination does not appear to be responsible for the rate-enhancing properties of houselight illumination onset. First-component response rates under the OFF/ON/ON conditions of the present experiment were 5 to 700 times that under the ON/ON/ON condition despite reductions in the similarities of feederlight and houselight illumination. However, it should be noted that the absolute response-rate enhancement during the first component of the OFF/ON/ON condition of the present experiment was less than that during Experiment Three for birds 1150 and 2225. Thus, although the similarity between the feeder light and houselight illumination may have contributed to the enhancement in first-component response rates under the OFF/ON/ON

condition of Experiment Three, the apparent reinforcing efficacy of houselight illumination onset either must be the result of some unidentified establishing operation, may represent the irreversible effects of previous similarities between feederlight and houselight illumination, or houselight illumination onset may function as an unconditioned reinforcer under the present experimental procedures. Regardless of the source of the rate-enhancing properties of contingent houselight illumination onset, the existence of this phenomenon bears on several important areas of research as outlined in the General Discussion.

CHAPTER SIX

GENERAL DISCUSSION

In each of the present experiments, the rate of responding within one component of a two- or three-component chained schedule of food presentation was increased substantially when the chamber houselight was illuminated at the completion of that component. Experiments One and Two demonstrated that this rate enhancement was the result of neither component stimulus control augmented by differential houselight illumination among component schedules, nor the disinhibition of responding previously suppressed by the presence of ambient illumination. Instead, the results of each experiment are consistent with the interpretation that the onset of houselight illumination functioned under these chained schedule arrangements as a positive reinforcer. Experiments Three and Four assessed two potential sources through which houselight illumination may have acquired conditioned reinforcing properties. The results of these two experiments suggest that the reinforcing efficacy of houselight illumination did not result through either temporal contiguity with the terminal components of the chained schedule arrangements or through stimulus induction

or generalization between the feederlight and houselight illuminations.

Other theoretical conceptualizations regarding the formation of conditioned reinforcers are not applicable to the present experimental procedures. The Delay Reduction Hypothesis (e.g., Fantino, 1969, 1977) might suggest that the houselight illuminated in only the later components of a chained schedule would function as a conditioned reinforcer by virtue of signalling a reduction in the time until the presentation of primary reinforcement. Uncertainty Reduction theories (e.g., Bloomfield, 1972; Hendry, 1969) also might suggest that the illuminated houselight, differentially associated with the later components of a chained schedule, would acquire reinforcing properties by providing "information" or a reduction in uncertainty regarding the presentation of primary reinforcement. However, in all conditions in the present series of experiments, the illuminated houselight was accompanied by and redundant with the component keylight (or key feature) stimuli and thus, should demonstrate no greater reinforcing efficacy than the component stimuli.

It is unclear at present whether houselight illumination functions as an unconditioned reinforcer or if the rate-enhancing properties of houselight onset represents the irreversible effects of some unexamined establishing operation. Regardless of the etiology of the reinforcing characteristics of houselight onset, the present results

bear on two important classes of experimentation; (1) research in which changes in illumination have been shown to reinforce responding; and (2) research in which changes in illumination have been employed as arbitrary or neutral experimental stimuli.

Numerous studies have shown that the onset of illumination can function to reinforce responding (e.g., Girdner, 1953a,b; Kish, 1955; Kling, Hurwitz, & Dalhagen, 1956; Marx, Henderson, & Roberts, 1955; Segal, 1959; Stewart, 1960). Other studies report that the termination of illumination can function as a reinforcer (e.g., Barry & Symmes, 1963; Keller, 1941; Roberts, Marx, & Collier, 1958). These data have led to the inclusion of changes in illumination (either onset or termination) in a suggested class of stimuli termed Sensory Reinforcers (Kish, 1966), the rate-enhancing efficacy of which are derived neither through an identified "need" or deprivation state, nor association with an established reinforcer. Although the results of the present series of experiments can be related to these findings, the magnitude of the present effect is several times as great as that reported in previous studies. For individual subjects in the present study, the increase in first component response rates when the onset of houselight illumination occurred in the second component schedule was as great as 25 responses per minute (P-1150 in Experiment Four). In contrast, the corresponding rate enhancements under previous experimental arrangements were on the order of 1 to 3

responses per minute (e.g., derived from Stewart, 1960). These differences in levels of responding might be attributed to procedural differences between the present and previous experiments. These differences include: (1) the use of pigeons as subjects rather than mice (e.g., Kish, 1955), rats (e.g., Hurwitz & Appel, 1959), or monkeys (e.g., Moon & Lodahl, 1956); and (2) the superimposition of illumination change upon an existing food reinforcement schedule rather than presented as the sole consequence of responding under either continuous or intermittent reinforcement contingencies (Stewart, 1960).

In the last thirty years a growing body of evidence has shown that the strength of "weak" reinforcers including water for non-fluid deprived subjects (e.g., Falk, 1961; Magyar & Malagodi, 1981), access to aggress against constrained conspecifics (e.g., Azrin, Hutchinson, & Hake, 1966; Allen, Sicignano, Webbe, & Malagodi, 1980), stimulus change (e.g., Brown & Flory, 1972), and wheel-running (e.g., Levitsky & Collier, 1968) is augmented by the presence of a background schedule of food reinforcement. Similar schedule induction (Falk, 1971; Staddon, 1977) from the ongoing chained schedule of food presentation, may have facilitated the typically low reinforcement strength of illumination onset under the present experimental conditions. Thus, while the current results may have provided an important extension of the generality of illumination reinforced responding to a new species, it may be more significant for

the demonstration of a more sensitive and generalizable procedure for the study of "weak" reinforcers.

The present results also bear on studies in which changes in houselight illumination have been employed as arbitrary experimental stimuli. In experiments in which subjects have been shown to terminate or escape from schedules of positive reinforcement (i.e., respond to initiate timeouts), changes in houselight illumination (either onset or termination) have been correlated with the timeout periods (e.g., Appel, 1963; Azrin, 1961; Brown & Flory, 1972; Dardano, 1973; Thomas & Sherman, 1965; Thompson, 1964). Similarly, houselight presentations have been correlated with extinction periods interpolated within FI schedules of food presentation in an assessment of the temporal control of responding (e.g., Dews, 1962, 1965a,b, 1966a,b). The present results, in conjunction with previous demonstrations of illumination-reinforced responding, suggest reexamination of the interpretations of the results generated under the above described procedures with respect to the assumed neutrality of the houselight stimuli employed.

A closely related area of research in which houselight illumination has been employed as a "neutral" experimental stimulus involves the analysis of performances maintained under second-order brief-stimulus schedules (Kelleher, 1966b). Under a brief-stimulus schedule the completion of a unit or component schedule is accompanied by a momentary

(e.g., 1.0-s) stimulus presentation. If the brief-stimulus presentation accompanies each component schedule completion, including that ending with the delivery of primary reinforcement, the brief stimulus is said to be paired. Conversely, if the brief-stimulus presentation accompanies the completion of each component schedule with the exception of that ending in the delivery of primary reinforcement, the brief stimulus is referred to as nonpaired. The comparison of responding maintained under comparable paired and nonpaired brief-stimulus schedules has constituted a major segment of contemporary research in the area of second-order schedules and conditioned reinforcement. Unfortunately, the results from these comparisons have been inconsistent.

In one set of experiments, clear differences in performance were maintained under the two forms of brief-stimulus schedules, with the paired brief-stimulus arrangement generating higher overall response rates and/or greater component-schedule response patterning than the nonpaired brief-stimulus counterparts (Byrd, 1972; Byrd & Marr, 1969; de Lorge 1967, 1969, 1971; Kelleher, 1966a,b); Malagodi et al., 1973; Marr, 1969; Stubbs, 1969). These results were interpreted as demonstrating the conditioned reinforcing efficacy of stimuli paired with the presentation of primary reinforcement (Kelleher, 1966a; Marr, 1969) and are supported by studies in which paired brief stimuli maintain responding as the sole consequence of responding with alternative responses reinforced by food presentation

concurrently (e.g., Zimmerman, 1969), during another component of a multiple schedule (e.g., Cohen & Lentz, 1976; Cohen, Calisto, & Lentz, 1979; Thomas, 1969), or not at all (e.g., Kelleher, 1961). In another set of experiments, however, similar rates and patterns of responding were maintained under comparable paired and nonpaired brief-stimulus schedules (Cohen, Hughes, & Stubbs, 1973; Cohen et al., 1979; Hughes, 1973; Stubbs, 1971; Stubbs & Cohen, 1972). Interpretation of this indifference in performance emphasized the discriminative properties of brief-stimulus presentation (Stubbs, 1971).

In an influential article, Stubbs (1971) criticized the methodology of those studies showing differences between paired and nonpaired brief-stimulus schedule performances, noting that in most experimental comparisons physically different events comprised the paired and nonpaired stimulus arrays. The paired stimulus might consist of illumination of the feeder mechanism, while a change in keylight color might constitute the nonpaired stimulus. Such discrepancies in the saliency of experimental stimuli were suggested by Stubbs (1971) to be responsible for any observed differences in the performances under comparable paired and nonpaired brief-stimulus schedules. When identical stimuli were employed as paired and nonpaired brief stimuli, comparable rates and patterns of responding were maintained under the two forms of brief-stimulus schedules (Cohen et al., 1973; Cohen et al., 1979; Hughes, 1973; Stubbs, 1971; Stubbs &

Cohen, 1972). Close examination of the brief-stimulus complex used in each of these experiments, however, also reveals a systematic stimulus bias. In each experiment, a change in houselight illumination constituted a major component of the brief-stimulus complex. Given the results of the present series of experiments, and those of previous studies demonstrating illumination-reinforced responding, changes in illumination would be inappropriate for use in the assessment of the reinforcing properties of stimuli associated with the presentation of primary reinforcement.

A recent experiment (Kupfer & Malagodi, in preparation) addressed these stimulus considerations in a comparison of performances under comparable paired and nonpaired brief-stimulus schedules. The paired brief stimulus consisted of a short (i.e., 0.75-s) change in keylight color and the nonpaired brief stimulus consisted of either the identical stimulus or a 0.75-s illumination of the chamber houselight. For each subject, use of the houselight-nonpaired brief stimulus resulted in both the greatest local rate of responding and component-schedule response patterning. Little or no response patterning was maintained under the component schedule when a nonpaired-keylight brief stimulus accompanied component completion. Finally, component-schedule response patterning under the paired brief-stimulus schedule arrangement significantly exceeded that under the nonpaired-keylight brief-stimulus schedules. These results suggest that (1) the onset of houselight illumination can

function as a positive reinforcer under a second-order brief-stimulus schedule and (2) the exclusion of stimuli with pre-experimental reinforcing properties from the brief-stimulus complex allow the observation of important differences in the performances maintained under comparable paired and nonpaired brief-stimulus schedules.

Only slowly do we come to understand the complexities of the variables controlling behavior. Often events we assume to have consist reinforcing, punishing, or neutral properties are employed in analysis of contingency relationships on performances only to have the results of such operations contradict our a priori assumptions regarding the nature of environmental events. What emerges is that specification of the behavioral outcome of any environmental arrangement can not be made with confidence without knowledge of the properties of environmental events, the function of contingency relationships, and the interactions of the two. Experiments such as the present may help contribute to that confidence.

REFERENCES

Allen, R. F., Sicignano, A., Webbe, F. M., & Malagodi, E. F. (1980). Induced attack during ratio schedules of reinforcement: Implications for measurement of adjunctive behaviors. In C. M. Bradshaw, E. Szabadi, & C. F. Lowe (Eds.), Quantification of steady-state operant behavior (pp. 118-121). Amsterdam: Elsevier/North Holland Biomedical Press.

Appel, J. B. (1963). Aversive aspects of a schedule of positive reinforcement. Journal of the Experimental Analysis of Behavior, 6, 423-428.

Autor, S. M. (1960). The strength of conditioned reinforcers as a function of frequency and probability of reinforcement. Unpublished doctoral dissertation. Harvard University.

Autor, S. M. (1969). The strength of conditioned reinforcers as a function of frequency and probability of reinforcement. In D. P. Hendry (Ed.), Conditioned reinforcement (pp. 51-93). Homewood, IL.: The Dorsey Press.

Azrin, N. H. (1961). Time-out from positive reinforcement. Science, 133, 382-383.

Azrin, N. H., Hutchinson, R. R., & Hake, D. F. (1966). Extinction-induced aggression. Journal of the Experimental Analysis of Behavior, 9, 191-204.

Barry, H., & Symmes, D. (1963). Reinforcing effects of illumination change in different phases of the rat's diurnal cycle. Journal of Comparative and Physiological Psychology, 56, 117-119.

Beninger, R. J., & Milner, P. M. (1977). Conditioned reinforcement based on reinforcing electrical stimulation of the brain: Chain schedules. Physiological Psychology, 5, 285-289.

Bloomfield, T. M. (1972). Reinforcement schedules: Contingency or contiguity. In R. M. Gilbert and J. R. Millenson (Eds.), Reinforcement: Behavioral Analysis (pp. 170-199). New York: Academic Press.

Brown, P. L., & Jenkins, H. M. (1968). Autoshaping of the pigeon's key-peck. Journal of the Experimental Analysis of Behavior, 11, 1-8.

Brown, T. G., & Flory, R. K. (1972). Schedule-induced escape from fixed-interval reinforcement. Journal of the Experimental Analysis of Behavior, 17, 395-403.

Byrd, L. D. (1971). Responding in the pigeon under chained schedules of food presentation: The repetition of the stimulus during alternate components. Journal of the Experimental Analysis of Behavior, 16, 31-38.

Byrd, L. D. (1972). Responding in the squirrel monkey under second-order schedules of shock deliver. Journal of the Experimental Analysis of Behavior, 18, 155-167.

Byrd, L. D., & Marr, M. J. (1969). Relations between patterns of responding and the presentation of stimuli under second-order schedules. Journal of the Experimental Analysis of Behavior, 12, 713-722.

Cohen, S. L., Calisto, G., & Lentz, B. E. (1979). Separating the reinforcing and discriminative properties of brief-stimulus presentations in second-order schedules. Journal of the Experimental Analysis of Behavior, 32, 149-156.

Cohen, S. L., Hughes, J. E., & Stubbs, D. A. (1973). Second-order schedules: Manipulation of brief stimulus duration at component completion. Animal Learning and Behavior, 1, 121-124.

Cohen, S. L. & Lentz, B. E. (1976). Factors influencing responding under multiple schedules of conditioned and unconditioned reinforcement. Journal of the Experimental Analysis of Behavior, 26, 395-404.

Cohen, S. L., & Stubbs, D. A. (1976). Discriminative properties of briefly presented stimuli. Journal of the Experimental Analysis of Behavior, 25, 15-25.

Dardano, J. F. (1973). Self-imposed timeouts under increasing response requirements. Journal of the Experimental Analysis of Behavior, 19, 269-287.

de Lorge, J. (1967). Fixed-interval behavior maintained by conditioned reinforcement. Journal of the Experimental Analysis of Behavior, 10, 271-276.

de Lorge, J. (1969). The influence of pairing with primary reinforcement on the maintenance of conditioned reinforcement in second-order schedules. In D. P. Hendry (Ed.), Conditioned reinforcement (pp. 61-76). Homewood, IL: The Dorsey Press.

de Lorge, J. (1971). The effects of brief stimuli presented under a multiple schedule of second-order schedules. Journal of the Experimental Analysis of Behavior, 15, 19-25.

Dews, P. B. (1962). The effects of multiple s-delta periods on responding on a fixed-interval schedule. Journal of the Experimental Analysis of Behavior, 5, 369-374.

Dews, P. B. (1965a). The effects of multiple s-delta periods on responding on a fixed-interval schedule: II. In a primate. Journal of the Experimental Analysis of Behavior, 8, 53-54.

Dews, P. B. (1965b). The effects of multiple s-delta periods on responding on a fixed-interval schedule: III. Effect of changes in pattern of interruptions, parameters and stimuli. Journal of the Experimental Analysis of Behavior, 8, 427-435.

Dews, P. B. (1966a). The effects of multiple s-delta periods on responding on a fixed-interval schedule: IV. Effect of continuous s-delta with only short discriminative probes. Journal of the Experimental Analysis of Behavior, 9, 147-151.

Dews, P. B. (1966b). The effects of multiple s-delta periods on responding on a fixed-interval schedule: V. Effect of periods of complete darkness and of occasional omissions of food presentation. Journal of the Experimental Analysis of Behavior, 9, 573-578.

Falk, J. L. (1961). Production of polydipsia in normal rats by an intermittent food schedule. Science, 133, 195-196.

Falk, J. L. (1971). The nature and determinants of adjunctive behavior. Physiology and Behavior, 6, 577-588.

Fantino, E. (1969). Conditioned reinforcement, choice, and the psychological distance to reward. In D. P. Hendry (Ed.), Conditioned reinforcement (pp. 200-218). Homewood, IL: The Dorsey Press.

Fantino, E. (1977). Conditioned reinforcement: choice and information. In W. K. Honig & J. E. R. Staddon (Eds.), Handbook of operant behavior (pp. 313-339). Englewood Cliffs, NJ: Prentice-Hall.

Ferster, C. B., & Skinner, B. F. (1957). Schedules of reinforcement. New York: Appleton-Century-Crofts.

Findley, J. D. (1954). Rates of response in a two-member chain as a function of mean variable-interval schedule of reinforcement on the second member. Unpublished doctoral dissertation. Columbia University.

Findley, J. D. (1962). An experimental outline for building and exploring multi-operant behavior repertoires. Journal of the Experimental Analysis of Behavior, 5, 113-169.

Findley, J. D., & Brady, J. V. (1965). Facilitation of large ratio performance by use of conditioned reinforcement. Journal of the Experimental Analysis of Behavior, 8, 125-129.

Galbicka, G. (1981). Operant-Pavlovian interactions in chained-schedule performance of pigeons. Paper presented at the annual meeting of the Southeastern Psychological Association: Atlanta, GA.

Gardner, M. L., & Malagodi, E. F. (1981). Responding under sequence schedules of electric shock presentation. Journal of the Experimental Analysis of Behavior, 35, 323-334.

Girdner, J. B. (1953a). An experimental analysis of the behavioral effects of a perceptual consequence unrelated to organic drive states. American Psychologist, 8 (Abstract).

Girdner, J. B. (1953b). An experimental analysis of the behavioral effects of a perceptual consequence unrelated to organic drive states. Unpublished doctoral dissertation. Duke University.

Goldberg, S. R., Kelleher, R. T., & Morse, W. H. (1975). Second-order schedules of drug injection. Federation proceedings, 34, 1771-1776.

Gollub, L. R. (1958). The chaining of fixed-interval schedules. Unpublished doctoral dissertation, Harvard University.

Gollub, L. R. (1964). The relations among measures of performance on fixed-interval schedules. Journal of the Experimental Analysis of Behavior, 7, 337-343.

Gollub, L. R. (1977). Conditioned reinforcement: Schedule effects. In W. K. Honig & J. E. R. Staddon (Eds.), Handbook of operant behavior (pp. 288-312). Englewood Cliffs, NJ: Prentice-Hall.

Hanson, H. M., & Witoslawski, J. J. (1959). Interaction between the components of a chained schedule. Journal of the Experimental Analysis of Behavior, 2, 171-177.

Hearst, E., & Jenkins, H. M. (1974). Sign-tracking: The stimulus-reinforcer relation and directed action. Monograph of the Psychonomic Society: Austin, Texas.

Hendry, D. P. (1969). In D. P. Hendry (Ed.), Conditioned reinforcement (pp. 1-9). Homewood, IL: The Dorsey Press.

Herrnstein, R. J. (1961). Relative and absolute strength of response as a function of frequency of reinforcement. Journal of the Experimental Analysis of Behavior, 4, 267-272.

Herrnstein, R. J. (1964). Secondary reinforcement and the rate of primary reinforcement. Journal of the Experimental Analysis of Behavior, 7, 27-36.

Herrnstein, R. J., & Morse, W. H. (1957). Effects of pentobarbital on intermittently reinforced behavior. Science, 125, 929-931.

Hughes, J. E. (1963). Second-order schedules: A new procedure. Paper presented at the Eastern Psychological Association, Washington.

Hurwitz, H. M. B., & Appel, J. B. (1959). Light-onset reinforcement as a function of light-dark maintenance schedule for the hooded rat. Journal of Comparative and Physiological Psychology, 52, 710-712.

Jwaideh, A. R. (1973). Responding under chained and tandem fixed-ratio schedules. Journal of the Experimental Analysis of Behavior, 19, 259-267.

Kaufman, A., & Baron, A. (1969). Conditioned reinforcing and aversive aspects of the stimuli defining the components of a two-component chain. Genetic Psychology Monographs, 80, 151-201.

Kelleher, R. T. (1961). Schedules of conditioned reinforcement in experimental extinction. Journal of the Experimental Analysis of Behavior, 4, 1-5.

Kelleher, R. T. (1966a). Chaining and conditioned reinforcement. In W. K. Honig (Ed.), Operant Behavior: Areas of research and application (pp. 160-212). New York: Appleton-Century-Crofts.

Kelleher, R. T. (1966b). Conditioned reinforcement in second-order schedules. Journal of the Experimental Analysis of Behavior, 9, 475-483.

Kelleher, R. T., & Fry, W. T. (1962). Stimulus functions in chained fixed-interval schedules. Journal of the Experimental Analysis of Behavior, 5, 167-173.

Kelleher, R. T., & Gollub, L. R. (1962). A review of positive conditioned reinforcement. Journal of the Experimental Analysis of Behavior, 5, 543-597.

Kelleher, R. T., & Morse, W. H. (1968). Determinants of the specificity of behavioral effects of drugs. Ergebrisse der Physiologie, 60, 1-56.

Keller, F. S. (1941). Light aversion in the white rat. Psychological Record, 4, 235-250.

Keller, K. (1974). The role of elicited responding in behavioral contrast. Journal of the Experimental Analysis of Behavior, 21, 249-257.

Kish, G. B. (1955). Learning when the onset of illumination is used as a reinforcing stimulus. Journal of the Experimental Analysis of Behavior, 48, 261-264.

Kish, G. B. (1966). Studies of sensory reinforcement. In W. K. Honig (Ed.), Operant Behavior: Areas of research and application (pp. 109-159). New York: Appleton-Century-Crofts.

Kling, J. W., Hurwitz, L., & Dalhagen, J. E. (1956). Light as a positive reinforcer for rat responding. Psychological Reports, 2, 337-340.

Kupfer, J., & Malagodi, E. F. (1988). Effects of different types of brief-stimulus presentations on second-order schedule performances. Manuscript in preparation.

Lee, J. K., & Gollub, L. R. (1971). Second-order schedules with fixed-ratio components: Variation of component size. Journal of the Experimental Analysis of Behavior, 15, 303-310.

Levitsky, D., & Collier, G. (1968). Schedule-induced wheel running. Physiology and Behavior, 3, 571-573.

Magyar, R. L., & Malagodi, E. F. (1980). Measurement and development of schedule-induced drinking in pigeons. Physiology and Behavior, 25, 245-251.

Malagodi, E. F. (1967a). Acquisition of the token reward habit in the rat. Psychological Reports, 20, 1335-1342.

Malagodi, E. F. (1967b). Fixed-ratio schedules of token reinforcement. Psychonomic Science, 8, 469-470.

Malagodi, E. F. (1967c). Variable-interval schedules of token reinforcement. Psychonomic Science, 8, 471-472.

Malagodi, E. F., DeWeese, J., & Johnston, J. M. (1973). Second-order schedules: A comparison of chained, brief-stimulus, and tandem procedures. Journal of the Experimental Analysis of Behavior, 20, 447-460.

Malagodi, E. F., Webbe, F. M., & Waddell, T. R. (1975). Second-order schedules of token reinforcement: Effects of varying the schedule of food presentation. Journal of the Experimental Analysis of Behavior, 24, 173-181.

Marr, M. J. (1969). Second-order schedules. In D. P. Hendry (Ed.), Conditioned reinforcement (pp. 37-60). Homewood, IL: The Dorsey Press.

Marr, M. J. (1979). Second-order schedules and the generation of unitary response sequences. In M. D. Zeiler & P. Harzem (Eds.), Advances in analysis of behaviour: Vol. 1. Reinforcement and the organization of behaviour (pp. 223-260). Chichester, England: Wiley.

Marx, M. H., Henderson, R. L., & Roberts, C. L. (1955). Positive reinforcement of the bar pressing response by a light stimulus following dark operant pretests with no aftereffect. Journal of Comparative and Physiological Psychology, 48, 73-76.

Moon, L. E., & Lodahl, T. M. (1956). The reinforcing effect of changes in illumination on lever-pressing in the monkey. American Journal of Psychology, 69, 288-290.

Morse, W. H., & Kelleher, R. T. (1977). Determinants of reinforcement and punishment. In W. K. Honig and J. E. R. Staddon (Eds.), Handbook of operant behavior (pp. 174-200). Englewood Cliffs, NJ: Prentice-Hall.

Pavlov, I. P. (1927). Conditioned reflexes. London: Oxford University Press.

Roberts, C. L., Marx, M. H., & Collier, G. (1958). Light onset and light offset as reinforcers for the albino rat. Journal of Comparative and Physiological Psychology, 51, 575-579.

Robinson, P. W., & Shelley, M. F. (1974). The effects of total darkness on schedule control. Journal of the Experimental Analysis of Behavior, 22, 391-400.

Schwartz, B., & Gamzu, E. (1977). Pavlovian control of operant behavior. In W. K. Honig and J. E. R. Staddon (Eds.), Handbook of operant behavior (pp. 53-97). Englewood Cliffs, NJ: Prentice-Hall.

Segal, E. F. (1959). Confirmation of a positive relation between deprivation and number of responses emitted for light reinforcement. Journal of the Experimental Analysis of Behavior, 2, 165-169.

Skinner, B. F., & Morse, W. H. (1958). Fixed-interval reinforcement of running in a wheel. Journal of the Experimental Analysis of Behavior, 1, 371-379.

Staddon, J. E. R. (1972). Temporal control and the theory of reinforcement schedules. In R. M. Gilbert and J. R. Millenson (Eds), Reinforcement: Behavioral analyses (pp. 111-141). New York: Academic Press.

Stewart, J. (1960). Reinforcing effects of light as a function of intensity and reinforcement schedule. Journal of Comparative and Physiological Psychology, 53, 187-193.

Stubbs, A. (1969). Contiguity of briefly presented stimuli with food reinforcement. Journal of the Experimental Analysis of Behavior, 12, 271-278.

Stubbs, D. A. (1971). Second-order schedules and the problem of conditioned reinforcement. Journal of the Experimental Analysis of Behavior, 16, 289-313.

Stubbs, D. A., & Cohen, S. L. (1972). Second-order schedules: Comparison of different procedures for scheduling paired and nonpaired brief-stimuli. Journal of the Experimental Analysis of Behavior, 18, 403-413.

Thomas, J. R. (1969). Maintenance of behavior by conditioned reinforcement in the signalled absence of primary reinforcement. In D. P. Hendry (Ed.), Conditioned reinforcement (pp. 101-139). Homewood, IL: The Dorsey Press.

Thomas, J. R., & Sherman, J. A. (1965). Time out from a fixed-ratio schedule. Psychonomic Science, 3, 489-490.

Thompson, D. M. (1964). Escape from discriminative stimulus associated with fixed-ratio reinforcement. Journal of the Experimental Analysis of Behavior, 7, 1-8.

Waddell, T. R., Leander, J. D., Webbe, F. M., & Malagodi, E. F. (1972). Schedule interaction in second-order fixed-interval (fixed-ratio) schedules of token reinforcement. Learning and Motivation, 3, 91-100.

Wasserman, E. A. (1973). The effect of redundant contextual stimuli on autoshaping of the pigeon's keypeck. Animal Learning and Behavior, 1, 198-206.

Wasserman, E., Franklin, S., & Hearst, E. (1974). Pavlovian appetitive contingencies and approach vs. withdrawal to conditioned stimuli in pigeons. Journal of Comparative and Physiological Psychology, 86, 616-627.

Webbe, F. M., & Malagodi, E. F. (1978). Second-order schedules of token reinforcement: Comparisons of performance under fixed-ratio and variable-ratio exchange schedules. Journal of the Experimental Analysis of Behavior, 30, 219-224.

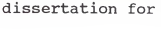
Zeiler, M. D. (1972). Fixed-interval behavior:d Effects of percentage reinforcement. Journal of the Experimental Analysis of Behavior, 17, 177-189.

Zimmerman, J. (1969). Meanwhile . . . back at the key: Maintenance of behavior by conditioned reinforcement and response-independent reinforcement. In D. P. Hendry (Ed.), Conditioned reinforcement (pp. 219-241). Homewood, IL: The Dorsey Press.

BIOGRAPHICAL SKETCH

Ron Allen was born in 1954 to Henry and Celia Allen. He was raised entirely in the state of Florida. He may be unique in that regard. He received both his undergraduate and graduate education at the University of Florida in the science and art of behavior analysis. In 1983, he was fortunate enough to marry Ms. Julia Ellinger and together they moved north to Massachusetts. Currently, he is 36 years of age, the father of Eric Michael Allen, and the founder/director of the Swansea Wood School located in Swansea, MA. He is definitely unique in these regards.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



E. F. Malagodi, Chairperson
Professor of Psychology

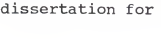
I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Marc N. Branch
Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

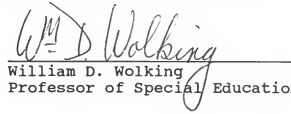
Henry S. Pennypacker
Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



Donald A. Dewsbury
Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



William D. Wolking
Professor of Special Education

This dissertation was submitted to the Graduate Faculty of the Department of Psychology in the College of Liberal Arts and Sciences and to the Graduate School and was accepted for partial fulfillment of the requirements for the degree of Doctor of Philosophy

May 1990

Dean, Graduate School